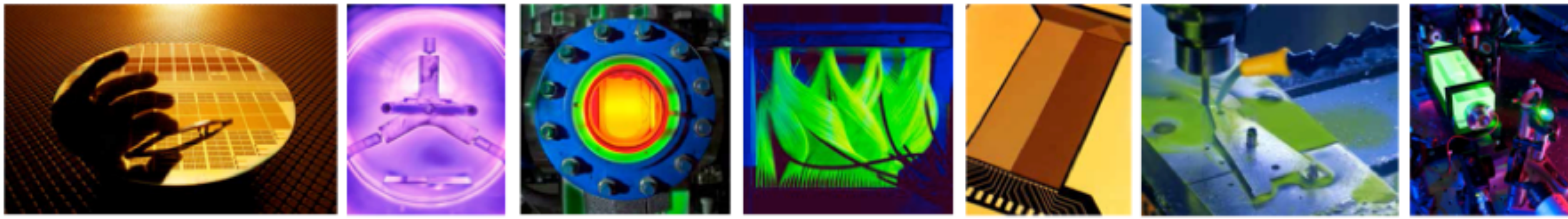


Laboratory Directed Research and Development (LDRD) – Fest
Some Early Results

Henryk Piekarz – HTS Accelerators
Phil DeMar – Network Analysis
Hogan Nguyn – CMB Detectors
Juan Estrada – Coherent Neutrino Interactions

William Wester

LDRD Coordinator

Joint Theoretical Experimental Seminar Apr 3 2015

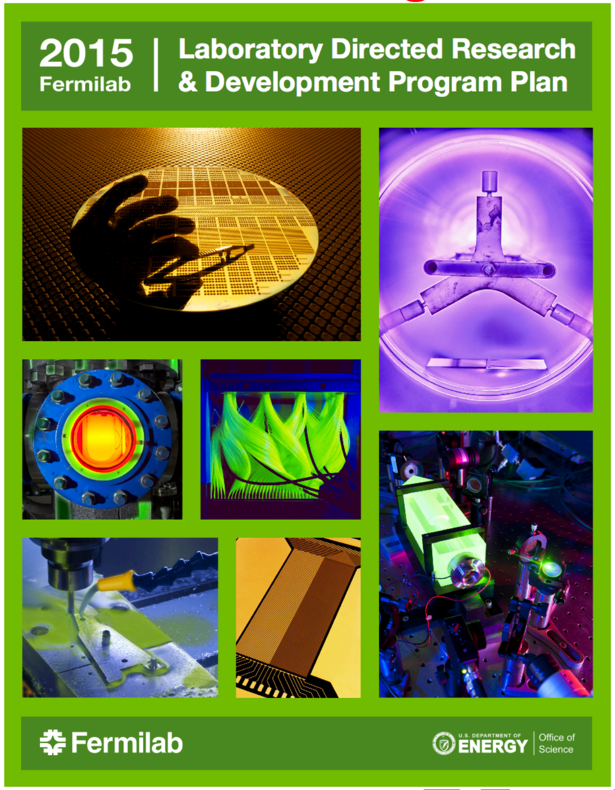
LDRD at Fermilab

- Formal Program at all the national labs: DOE O 413.2B
- Employee-initiated ideas at the forefront of technology or science and aligned with the missions of Fermilab and DOE

ldrd.fnal.gov

- Improves scientific/technical vitality
- Proof-on-concept ideas
- Outside of programmatic activities
- No more than 36 months
- Typical project is 2 years, <$500K total and includes fully burdened salaries and materials

- Next Call should be end of April



LDRD Projects

- FY14: 50 Preliminary, 26 Full Proposals, 7 funded
- FY15: 34 Preliminary, 10 Full Proposals, 6 funded

LDRD-2014-010	Brad Benson	Cosmic Microwave Background Detector Development at Fermilab
LDRD-2014-038	Phil DeMar	Application-Oriented Network Traffic Analysis based on GPUs
LDRD-2014-028	Juan Estrada	Deployment and operation of a prototype CCD array at Reactor Site for detection of Coherent Neutrino-Nucleus Interaction
LDRD-2014-027	Sarah Lockwitz	From Magic to Method: Characterizing High Voltage in Liquid Argon TPCs with Breakdown in liquid argon cryostat for high voltage experiments
LDRD-2014-012	Henryk Piekarz	Development of HTS Based Rapid-Cycling Accelerator Magnets
LDRD-2014-016	Greg Saewert	HF GaN Driver
LDRD-2014-025	Bob Zwaska	The Sinuous Target

LDRD-2015-020	Ryan Rivera	Off-the-Shelf Data Acquisition System
LDRD-2015-029	Alexander Romanenko	Nb_3Sn superconducting RF cavities to reach gradients up to 90MV/m and enable 4.2K operation of accelerators
LDRD-2015-021	Victor Scarpine	Transverse and Longitudinal Profile Diagnostics for H- Beams using Fiber Lasers and Synchronous Detection
LDRD-2015-010	Marcelle Soares-Santos	Dark Energy Survey and Gravitational Waves
LDRD-2015-031	Alexander Valishev	A comprehensive investigation of a transformational integrable optics storage ring as a “smart” rapid cycling synchrotron for high-intensity beams
LDRD-2015-009	Michael Wang	High Energy Physics Pattern Recognition with an Automata Processor

HTS-Based Fast-Cycling Accelerator Magnet

L2014.012 Proposal, Starting date: July 1, 2014

Henryk Piekarz, James Blowers and Steve Hays

Intended applications:

(1) Fast acceleration of high-intensity proton beams
(2) Fast acceleration of electron and positron beams
(3) Rapid acceleration of μ^+ and μ^- beams

Application (1) is the most likely one to be implemented in future upgrade(s) of Fermilab accelerator complex, and as such it is the most consistent with the LDRD goals. In this presentation we will focus on this application.

Attributes of HTS-Based Magnet for Fast Acceleration

- *Low cable power losses due to strongly minimized cable mass: current density of HTS ≥ 200 x current density of Cu*
- *Near suppression of cable dynamic power losses due to small cable cross-section in combination with a specific cable arrangement and core design*
- *Quench prevention due to wide operational temperature margin ($T_{quench} >> T_{operation}$)*
- *Near suppression of strand self-field coupling with Ni5%W substrates and tapes*

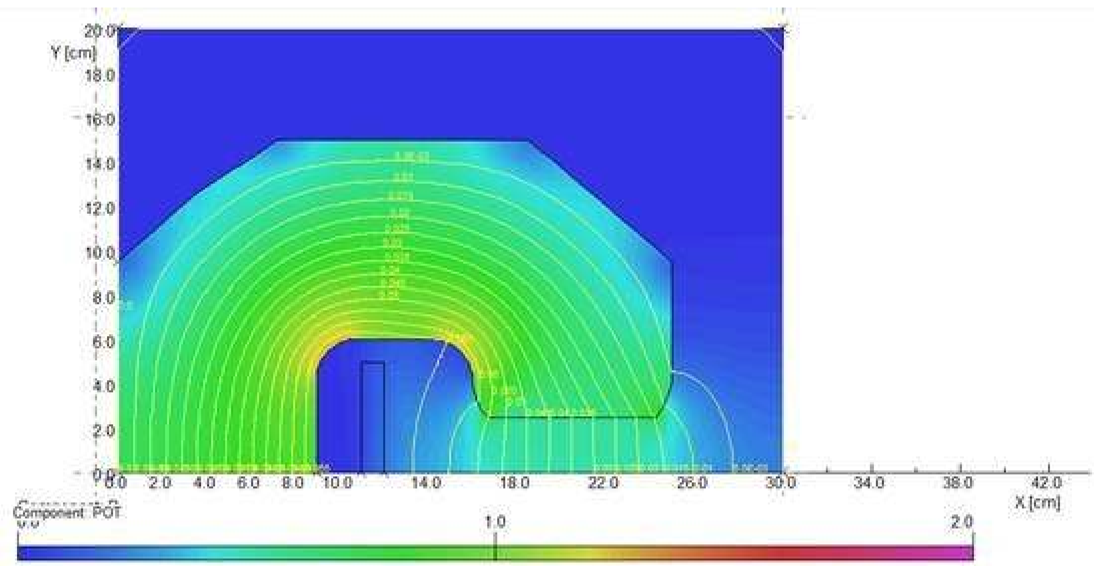


Fig. 1 Cable width and position within core cavity play substantial role in minimizing the strength of B-field crossing the cable space.

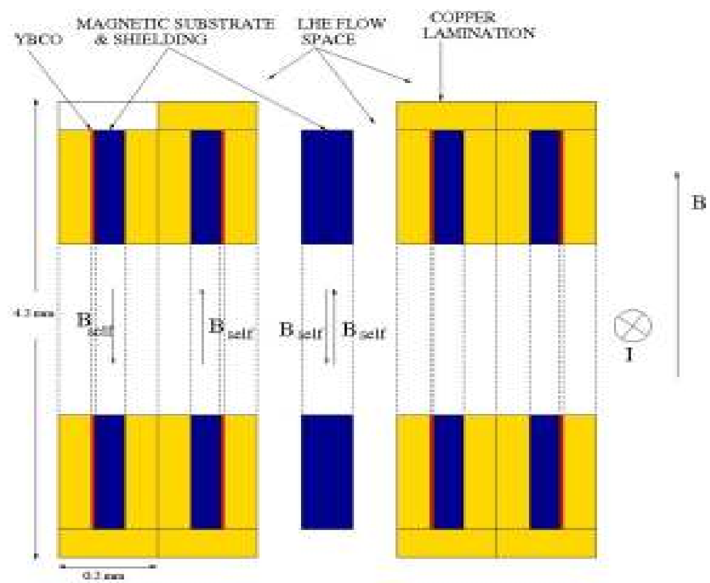
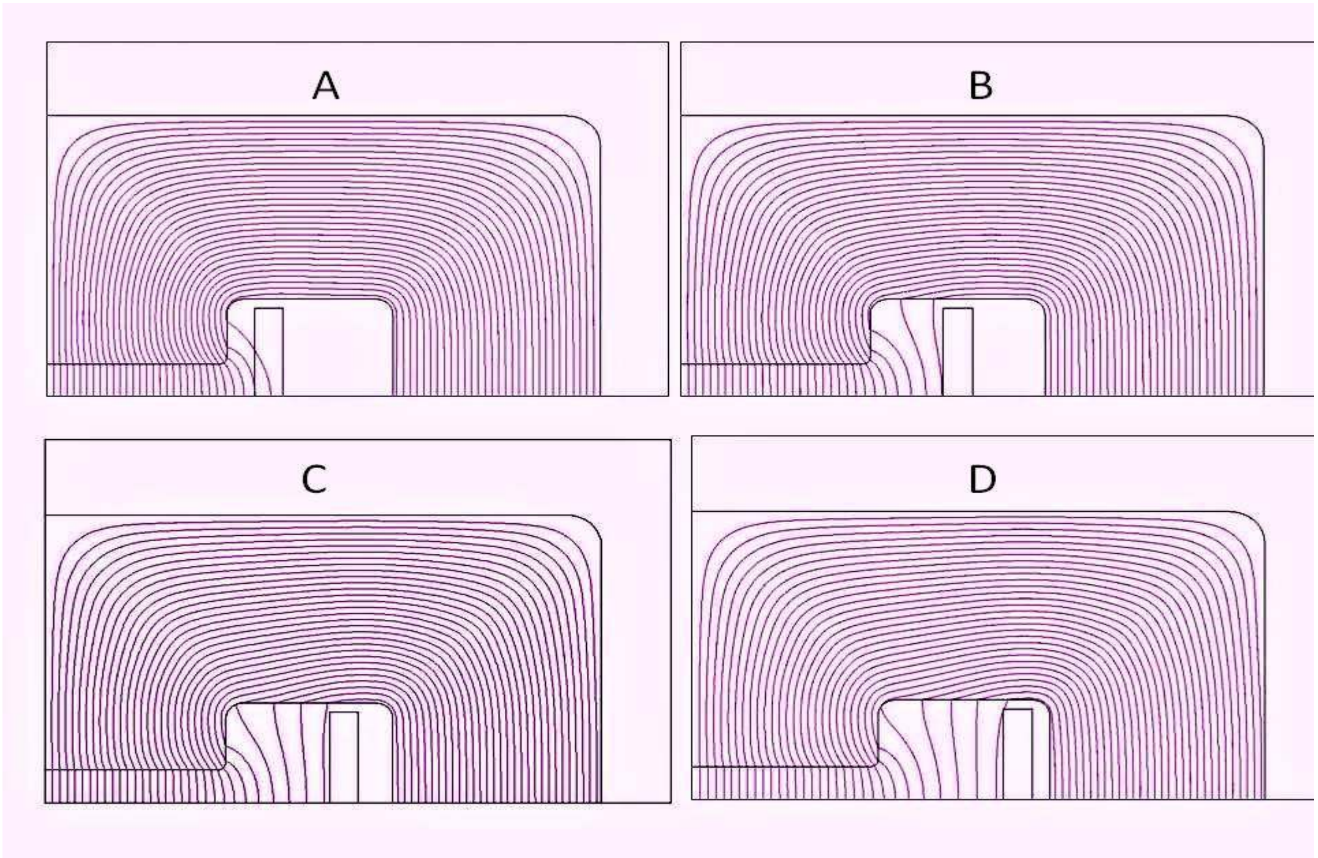


Fig. 2 With Ni5%W magnetic tapes within and between strand pairs only very low dynamic power losses are expected from the self-field coupling.

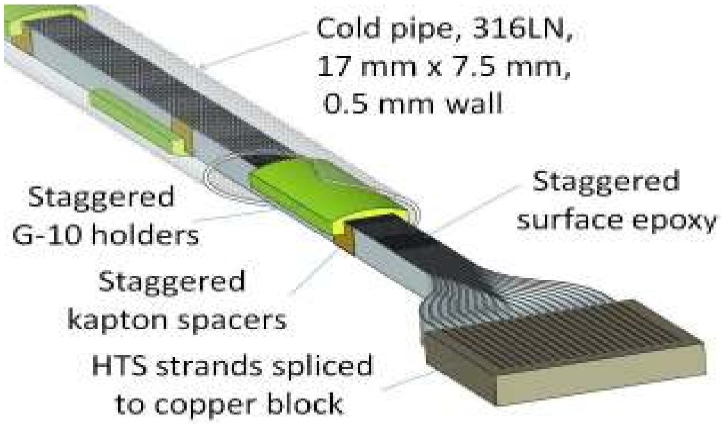
Cable position within magnet core & B-field crossing cable space



B-field descending from the core into cable space versus cable position.
It's also important that the cable is narrow and as high as possible.

HTS Cable Structure Options

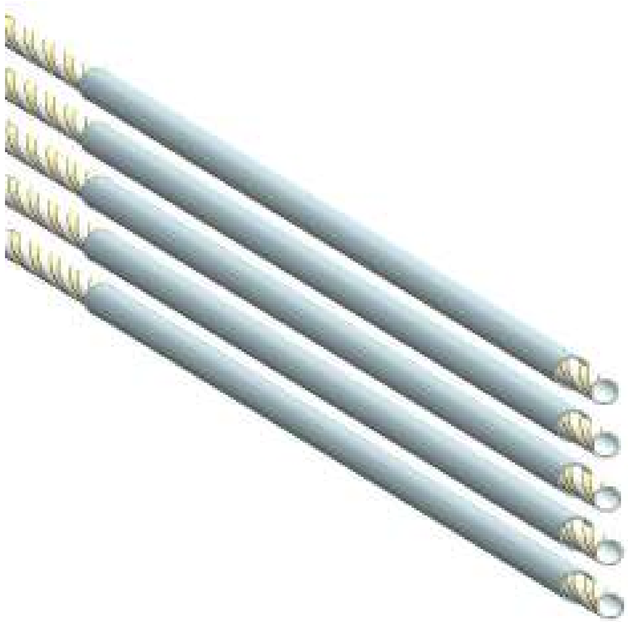
1 - Multiple wide or narrow HTS tapes stacked vertically



Sub-cable constructed of multiple wide YBCO tape strands stacked vertically and placed inside elliptical liquid helium channel. Stack of multiple sub-cables constitutes magnet cable. ***In a wide HTS tape the screen currents can lead to significant power losses if B-field descending from the core is not much suppressed.***

Technology for 4 mm wide strands is developed and a prototype cable was successfully tested in a cycling field of 20 T/s, equivalent to the beam gap cycling field of 1000 T/s.

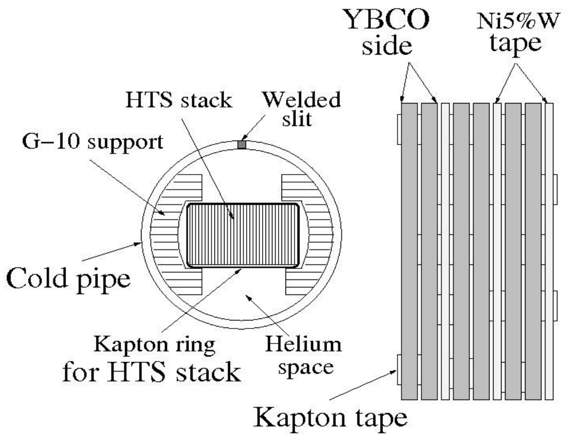
2 - Multiple narrow HTS tapes or wires wounded helically

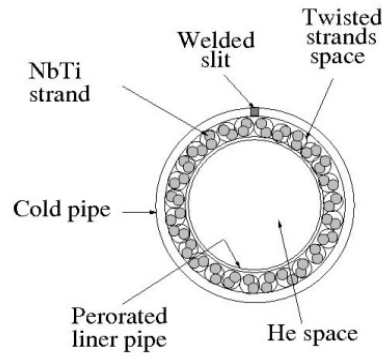


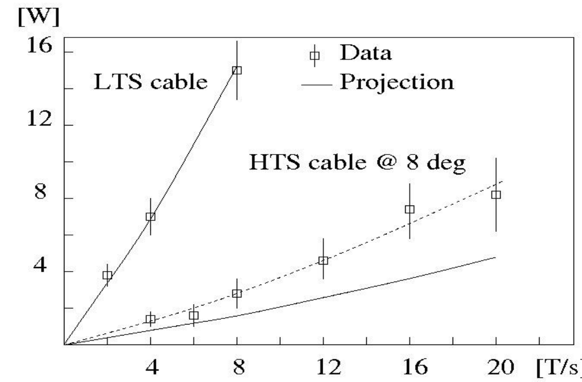
Sub-cables constructed of multiple narrow (2 mm) YBCO tapes, or (1 mm) MgB_2 wires. Two layers of strands are wounded helically crossing each other over the cable former. Strand's assembly is inside elliptical liquid helium channel. Stack of multiple sub-cables constitutes magnet cable.
This arrangement minimizes effect of screen currents, but the strand's self-field coupling may cause significant power loss.

Test of HTS Cable Power Loss in a Fast-Cycling Magnetic Field

Power loss measurement for 16 kA cables: 344C-2G (T_{quench} = 20 K) & NbTi (T_{quemch} = 6 K)





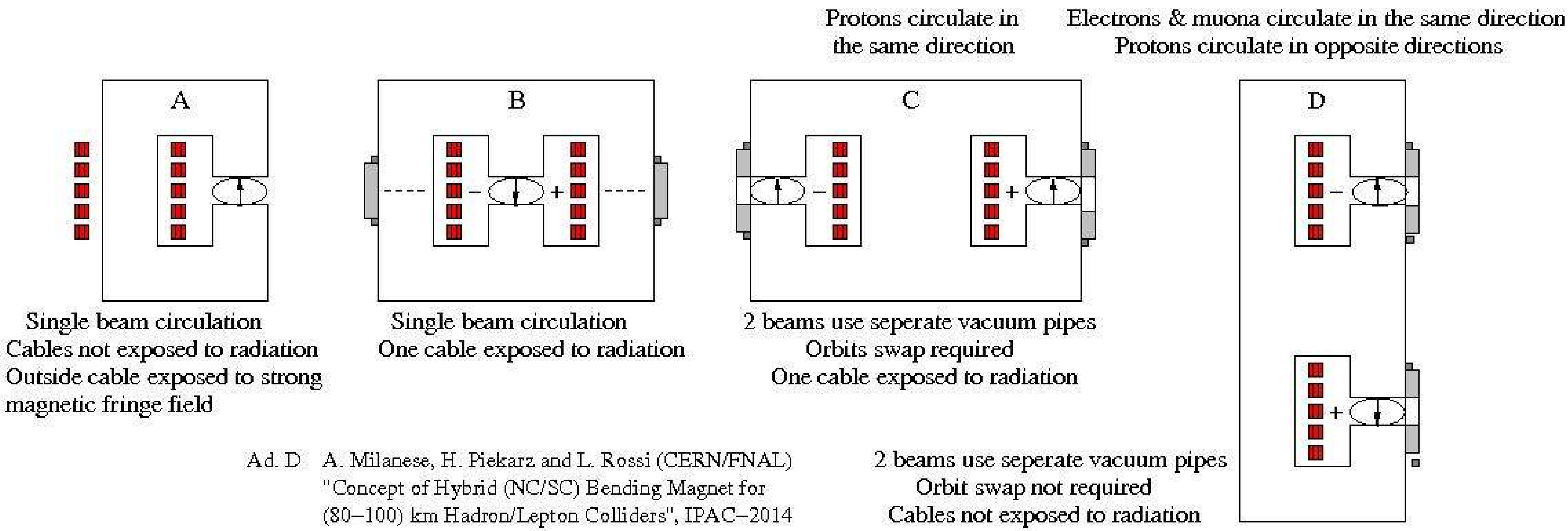


Data show losses for HTS stack at 8^0 relative to B-field assuming practical misalignment of strands.

HTS cable power loss at 8 T/s is 6 times lower than that of the LTS of the same critical current.

H. Piekarz, S. Hays, J. Blowers and V. Shiltsev "A Measurement of HTS Cable Power Loss in a Sweeping Magnetic Field", *Int. Conf. on Magnet Technology, MT-20, Marseille, IEEEE, Vol. 22, No 3 (2011)*

Magnet Core Choices



Option D:

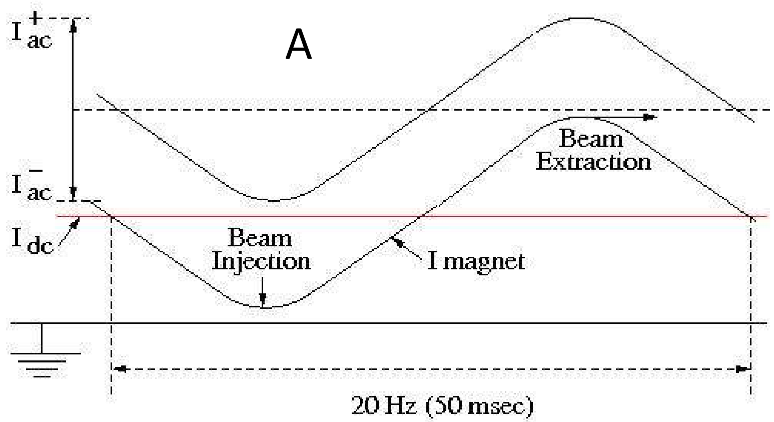
(i) Beams of opposite charges: (e^+, e^-), (μ^+, μ^-) & (P, Pbar) circulate in the same direction facilitating use of RF system for simultaneous acceleration of both beams.
Beam losses, decays and SR are emitted to the outside space of the magnet!

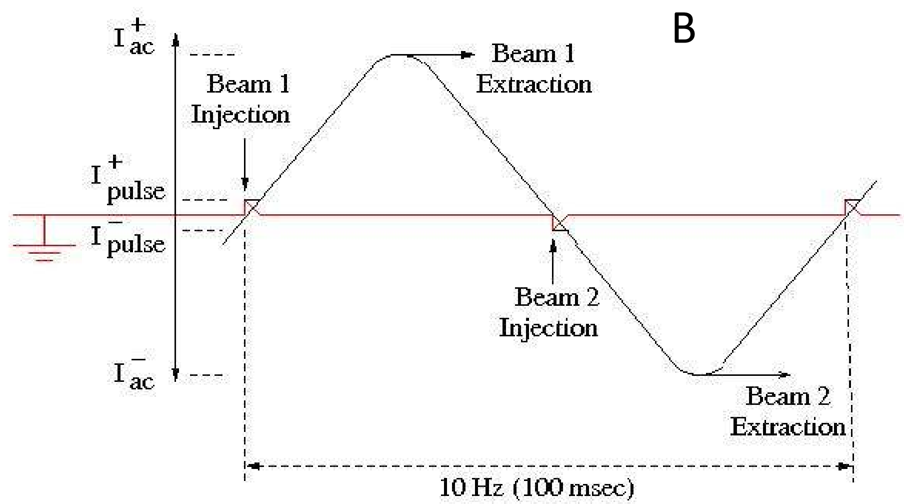
(ii) For two proton beams to circulate in the same direction B-field in the 2^{nd} gap must be reversed before beam injection into that gap. This can be achieved only if the two beam injections are staggered within the same RCS cycle.

Current Wave-Form for 2-Proton Beam Acceleration with D-Type Magnet

In a standard Booster application (Fig A) a single beam injection and extraction is during relatively flat (0.6 msec.) top and bottom of B-field sine-wave pulse. This method requires super-imposition of accelerating sine wave current over high DC current. One proton beam is accelerated per RCS cycle.

In a novel approach (Fig. B) small triangular current pulse is imposed on the primary sine-wave current creating short (e.g. 0.6 msec.) flat B-field. As a result of B-field reversal in the 2nd magnet gap both proton beams circulate in the same direction and 2 beams are accelerated per RCS cycle.





DC current is higher than AC to allow use of rising-only B-field for the acceleration. The RCS cycle must match LINAC one. Also the magnet power system must withstand high DC current when the AC component fails.

High DC current replaced with small AC pulse. Accelerating AC current is twice that of case A, but RCS cycle is ½ of the LINAC one.

Ramping Power Parameters versus Magnet Cable Arrangement

$L\,[H] = 4\,\pi \cdot 10^{-7} \cdot n^2 \cdot A_s\,[m^2] / H_g\,[m]$, $A_s = 0.1\ m^2$, $H_g = 0.05\ m$
$U\,[V] = L\,[H] \cdot dI/dt\,[A/s]$ (excluding cable resistive component, true for HTS cable)

$(dI/dt)_{max}\,[A/s] = U\,[V] / L\,[H]$, ***$(dI/dt)_{max}$ (U=1 V, L=1 μH) = 1 MA/s, a reasonable limit!***

Lower current benefits power supply construction, but at the expense of a more complicated magnet cable assembly.
A 3-turn HTS power cable constitutes reasonable compromise.

Parameters				
Number of conductor turns	[n]	1	3	6
Current/sub-cable	[kA]	24	8	4
dI/dt	[kA/s]	480	160	80
Magnetic inductance	[μH/m]	2.7	24.3	97
Magnet string length	[m]	20	20	20
Inductance/string	[μH]	54	486	1944
Voltage rise/string	[V]	26	78	156
dI/dt_{max}	[MA/s]	0.5	**0.16**	0.08
Ramping power/string	[kVA]	624	624	624
Number of strings		20	20	20
Ramping power/RCS	[MVA]	12.5	12.5	12.5

Expected Cooling Power for 8 GeV HTS-Based Booster

RCS Parameters (preliminary)		
Energy inj/extr	[GeV/GeV]	0.8/8
Circumference	[m]	400
Beam gap	[mm]	50
Dipole field inj/extr	[T/T]	0.05/0.5
Dipole current	[kA]	22
Frequency	[Hz]	10
dI/dt	[kA/s]	440
dB/dt beam gap	[T/s]	10
dB/dt cable space	[T/s]	0.5
SC strand type/width		YBCO/4mm
Number strands/cable		60
Strand length/magnet-m	[m]	60
Magnet cable power loss @ 5K	[W/m]	0.4
RCS cable power loss @ 5 K *)	**[W]**	**160**
RCS cable line power **)	**[kW]**	**48**
Core lamination		Fe3%Si/0.1 mm
Core power loss	[W/m]	0.025
RCS core power loss	[W]	10

***) 24 kW @ 5 K used by the TEVATRON**

****) 1.8 MW for 8 GeV Booster with Cu cable**

Cable power losses estimated using data from ref. [1] and with assumed 5% level of beam gap B-field crossing the cable space, as indicated in Fig. 1, slide #2.

Conclusions:

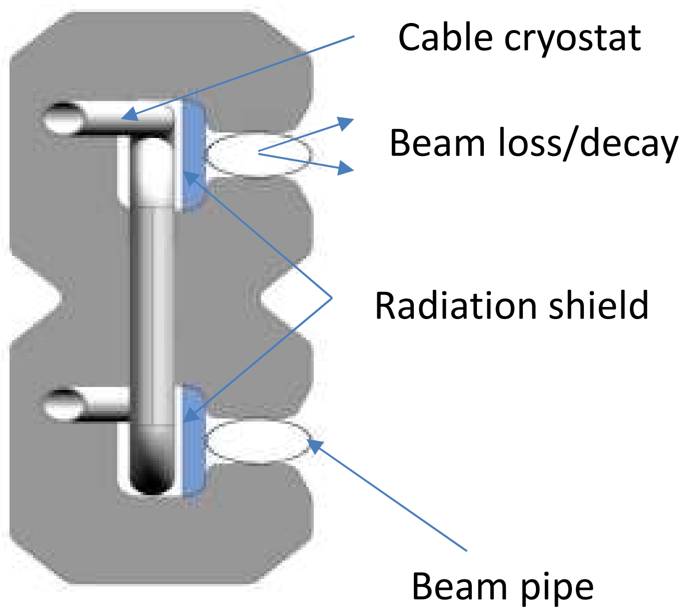
It is not too unlikely that required electric line power for cooling the 8 GeV HTS-based Booster can be about 1/40 of the power required to cool the current copper-based Booster magnets.

The low power loss of HTS-RCS may allow to increase RCS cycling rate and hence further increase the overall proton beam intensity.

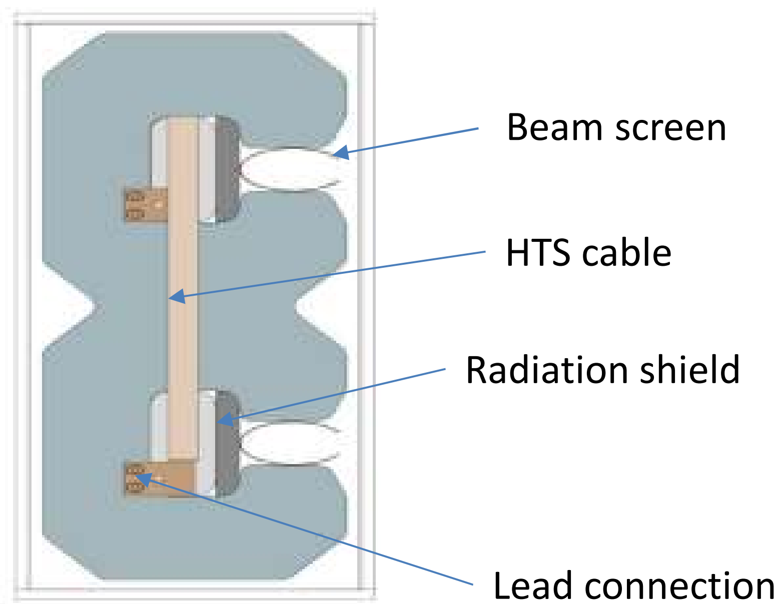
In such a case the onus will be on the LINAC to operate at higher frequency than currently anticipated (PIP II) to further increase the overall proton beam production.

Arrangements of HTS Magnet for Dual Beam Acceleration

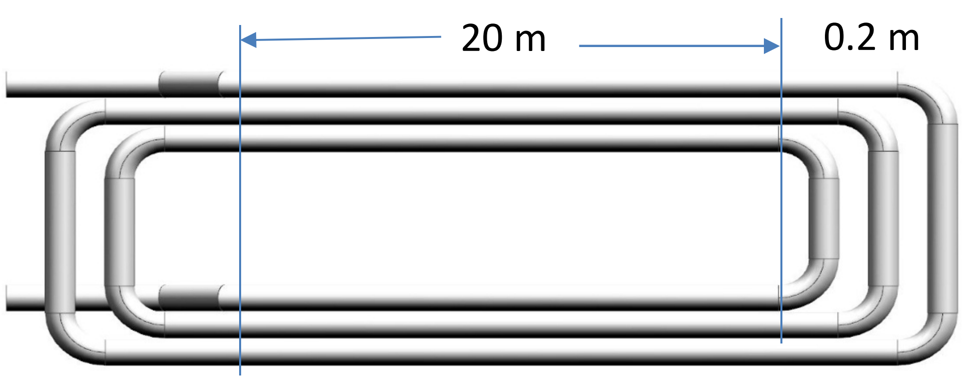
Sub-cables use individual cryostat pipes



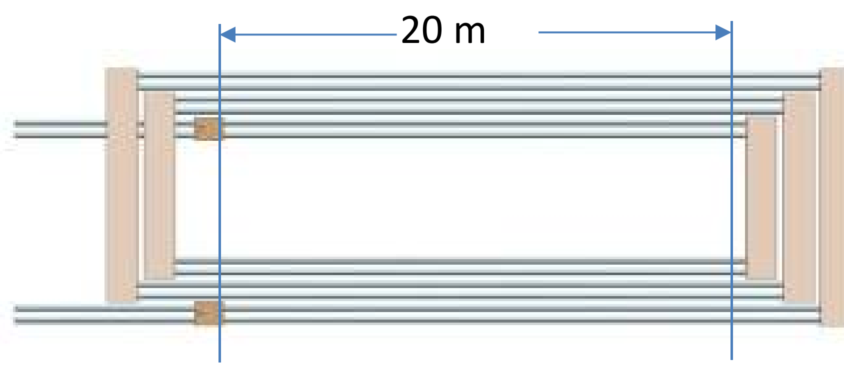
Sub-cables and magnet core are both inside cryostat



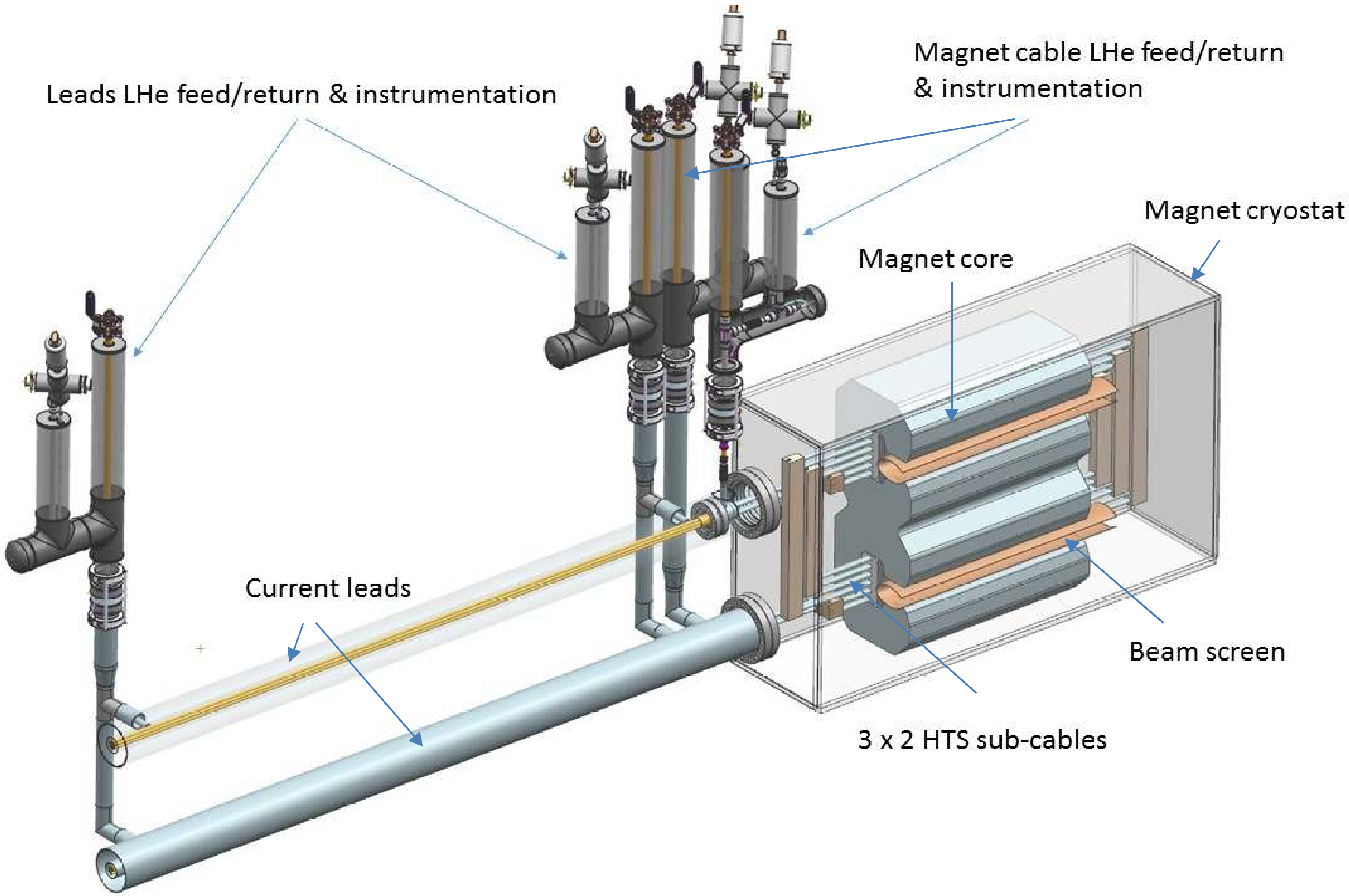
3-turn sub-cable in cryostat pipe



3-turn sub-cable – cold pipes only



Fast-Cycling LDRD Test-Magnet Proposal



Magnet length 0.5 m, Gap 100 mm x 50 mm, B-field 0.5 T, Current (+/- 8) kA per turn @ (10 -20)Hz

Managed by Fermi Research Alliance, LLC for the U.S. Department of Energy Office of Science

Application-Oriented Network Traffic Analysis based on GPUs

(LDRD Project Overview)

Wenji Wu; Liang Zhang, Phil DeMar (CS/CCD/NCS/NR)

Qiming Lu; Chris Green; Mike Wang; Jim Kowalkowski; Marc Paterno (CS/SCD/SSA/SSI/TAC)

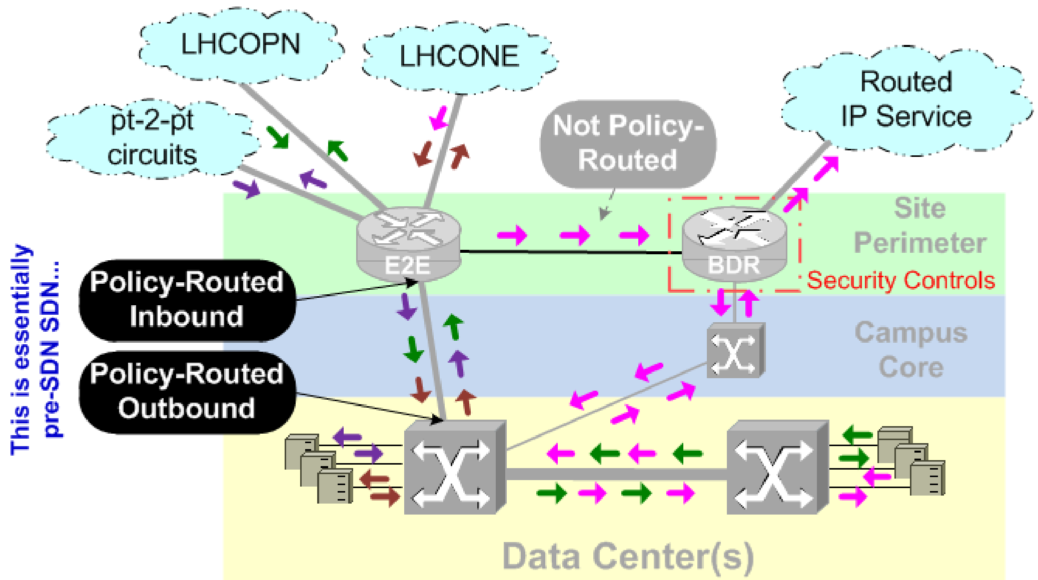
Ron Rechenmacher (CS/SCD/SSA/RSE/RSI)

April 3, 2015

Problem Space:

FNAL long-standing WAN strategy – isolate high-impact science data from general internet traffic:

- Separates elephants (bulk traffic) from mice (interactive traffic)
  - Largely for CMS data movement (right now…)
- Technically, separate network infrastructure is utilized:
  - But 100GE network infrastructure is expensive
  - Physically separate infrastructure is inflexible
  - Static allocation of network resources is inefficient



Problem Space (cont):

Software-Defined Networking (SDN):

- Emerging technology for dynamic network "configurability"
- Would facilitate customization of network packet forwarding:
  - Partition of network into "slices" for specified traffic flows (isolation…)
  - Enabling customization of network resource allocation as well

But how should SDN network reconfigurations be done?

- Manual (human) reconfiguration:
  - Inherently static & doesn't scale well to complex traffic patterns
- Application-driven reconfiguration:
  - Efficient, on-demand approach; scales well to complex patterns
  - But major software adaptation & maintenance burdens on developers

How about letting the network react to traffic patterns?

- This is our solution…

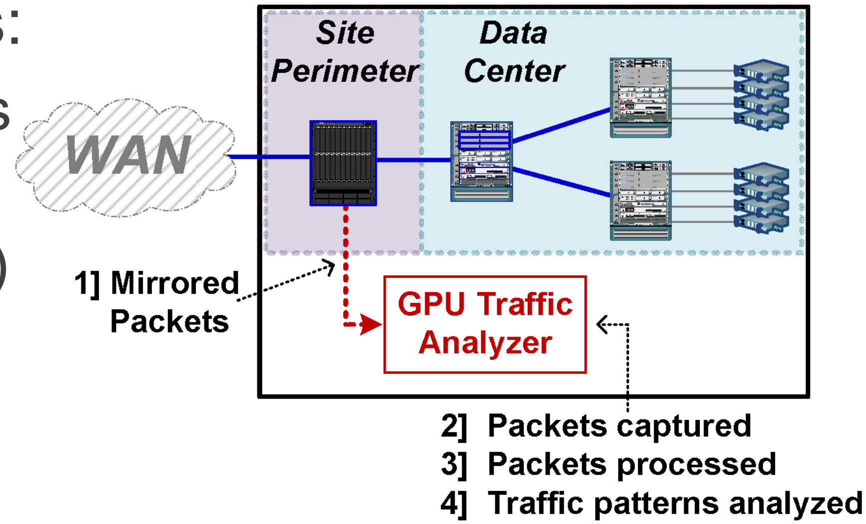
Proposed Solution

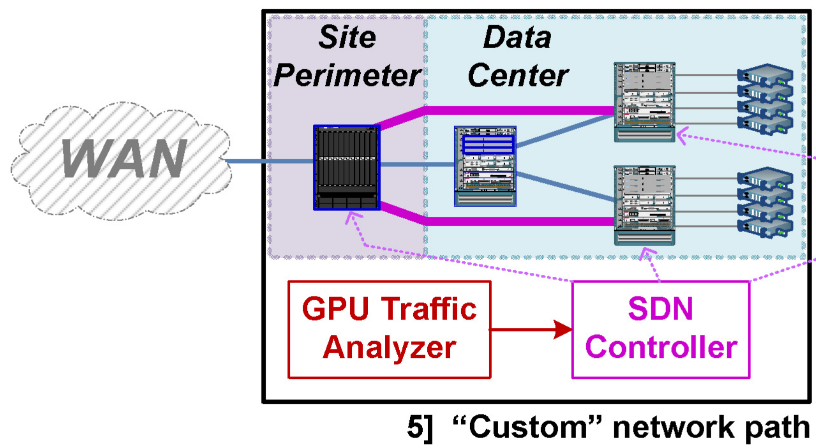
Tool to detect "special" traffic flows:

- Based on real-time packet analysis
- Output could result in modified network path characteristics (SDN)

Two major components:

- High-performance packet capture engine
- GPU-based network traffic pattern recognition algorithms:
  - Generic GPU libraries for packet manipulation within GPU domain
  - Custom GPU libraries for traffic pattern analysis





Use Case Walk-Thru

Use case assumptions:

- The Lab offers a cloud-like storage service to other facilities
- Usage is dynamic & non-predictive
- An approved template for storage service network slice exists

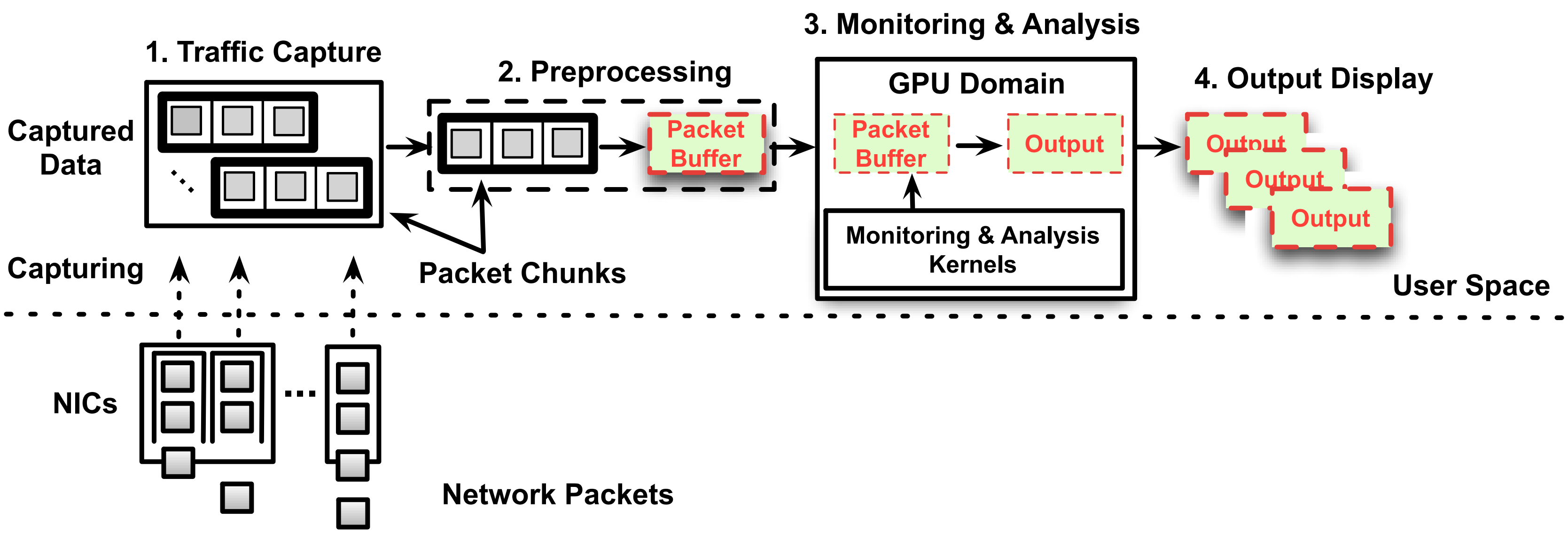
Use case sequence:

1. New customer initiates a storage request, resulting in traffic flows
2. Packets from those flows are mirrored to our analysis tool
3. Flows are determined to be storage service-related
4. If no network slice for the service currently exists, one is created:
   – With “appropriate” bandwidth (b/w) allocation
   – If a service slice already exists, additional b/w allocation is reserved
5. Our analysis tool detects end of flows for that service request
6. Service network slice is torn down (or appropriately reduced b/w)

System Architecture

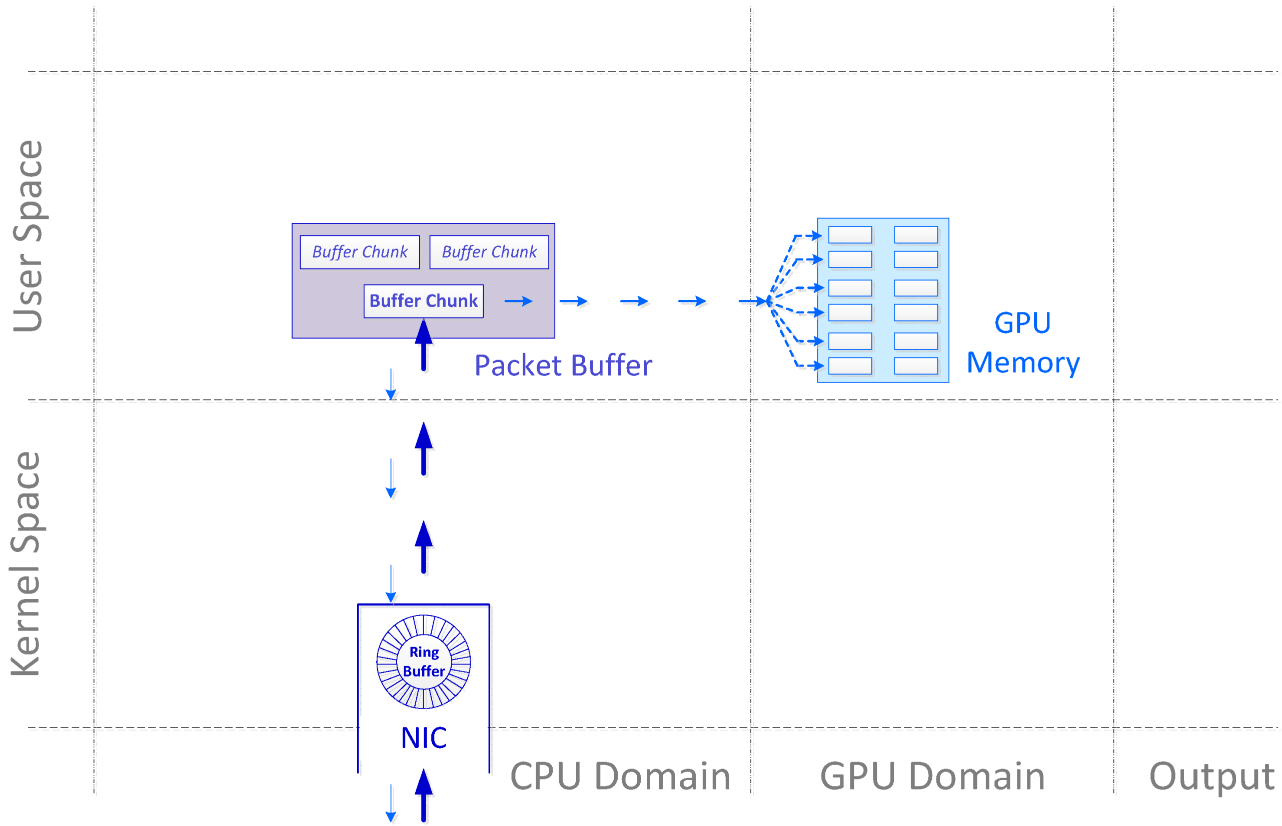
Four Types of Logical Entities:

1. Traffic Capture
2. Preprocessing
3. Traffic Analysis
4. Output (SDN controller configuration)



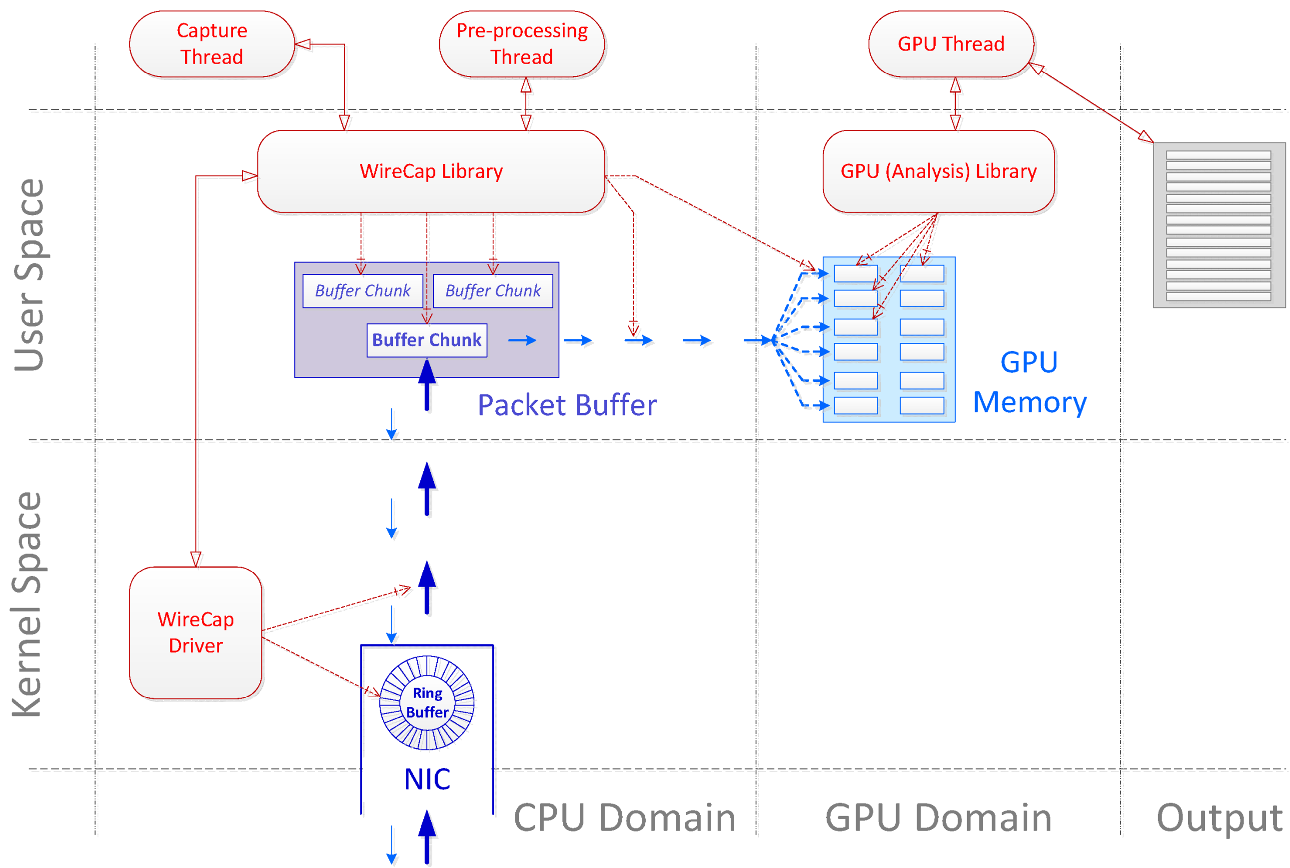
Design Components (I)

Data Plane – Packet Flow through the System



Design Components (II)

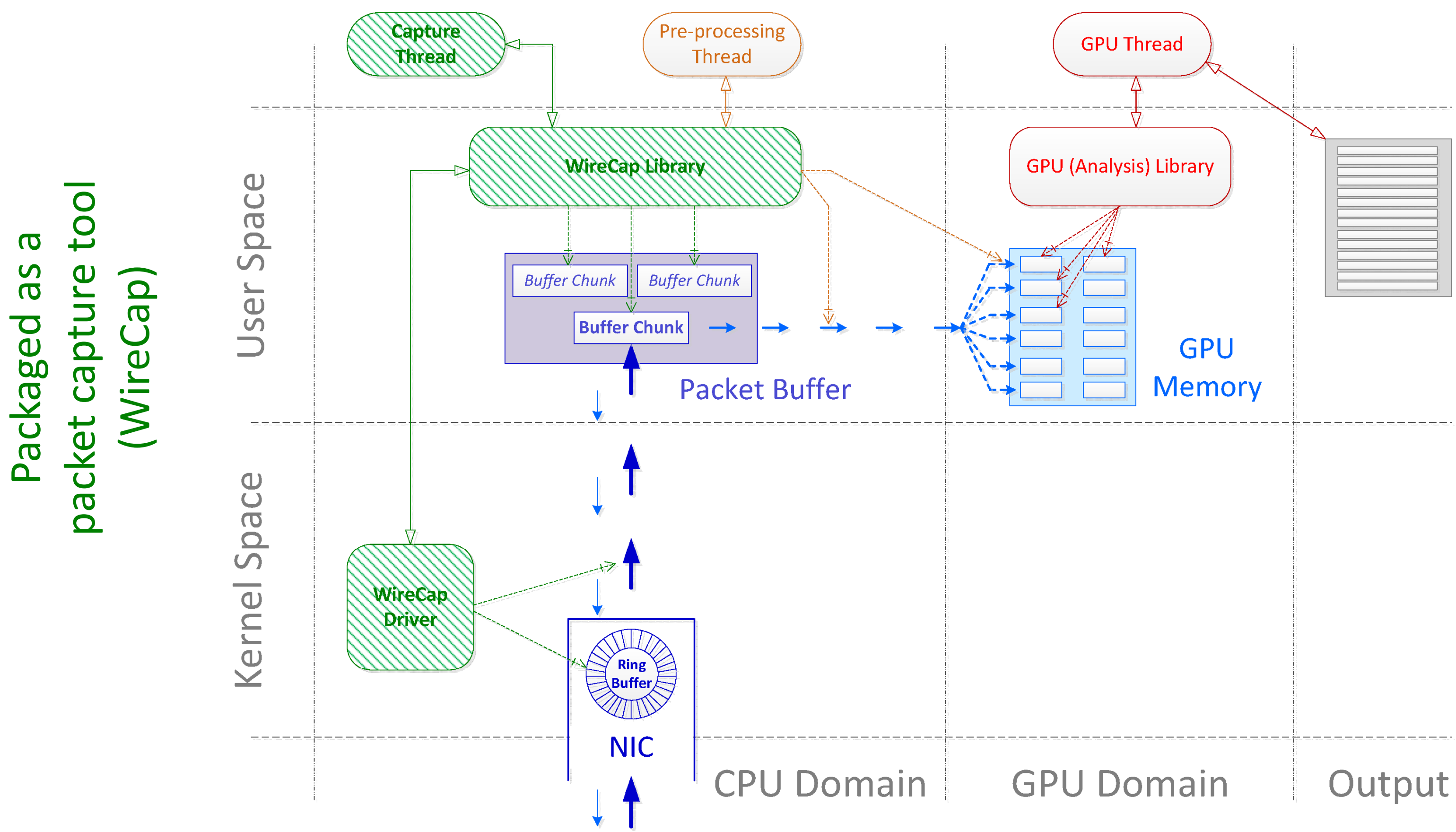
Control Plane – Software Design



Fermilab

Design Components (III)

Control Plane - Component Progress



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Project Objectives:

- Strategic:
  - Develop a generic platform with wider applicability
    - Security tool uses
    - Middlebox uses
    - Realtime network flow performance analysis uses
  - Target forward edge of network technology
    - Support for multiple NICs & advanced NICs
- Tactical:
  - Lossless packet capture engine
  - Capability for deep packet analysis
    - Although not needed for scope of this project…
  - Heuristic component in traffic identification

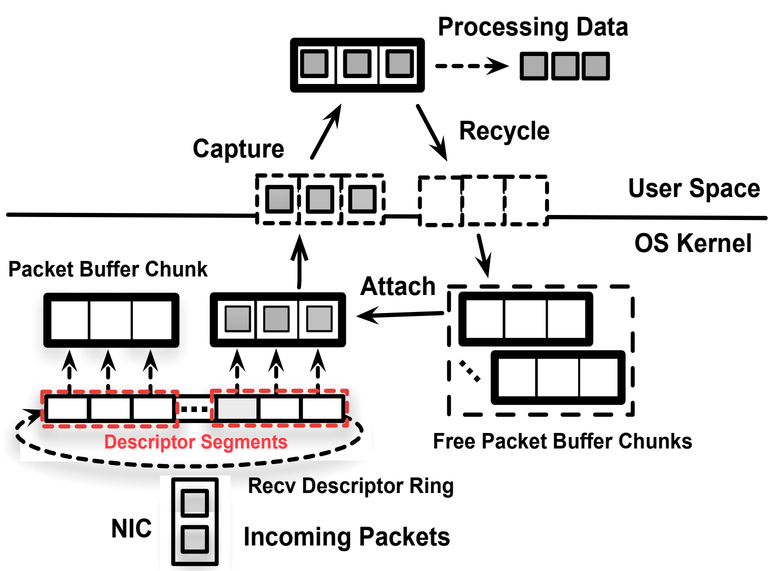
Project Status:

- Software development:
  - Prototype packet capture engine completed
    - Based on 10GE NICs; 40GE NICs currently being adapted
    - With retransmit function
  - Current development focus is on GPU packet processing
  - Expect functional prototype by year one milestone
    - With a very basic bulk traffic identification capability
  - Sophisticated traffic pattern analysis work will be in year two

- Odds & Ends:
  - Provisional patent filed on packet capture engine (WireCap)
  - Drawing interest in collaboration from R&D community
    - One silicon valley startup as well…

Extra Slides

Packet I/O Engine



Goal:

- To avoid packet capture loss

Key techniques

- A novel ring-buffer-pool mechanism
- Pre-allocated large packet buffers
- Packet-level batch processing
- Memory mapping based zero-copy

Key Operations

- Open
- Capture
- Recycle
- Close

CMB Detector Development at Fermilab

Brad Benson

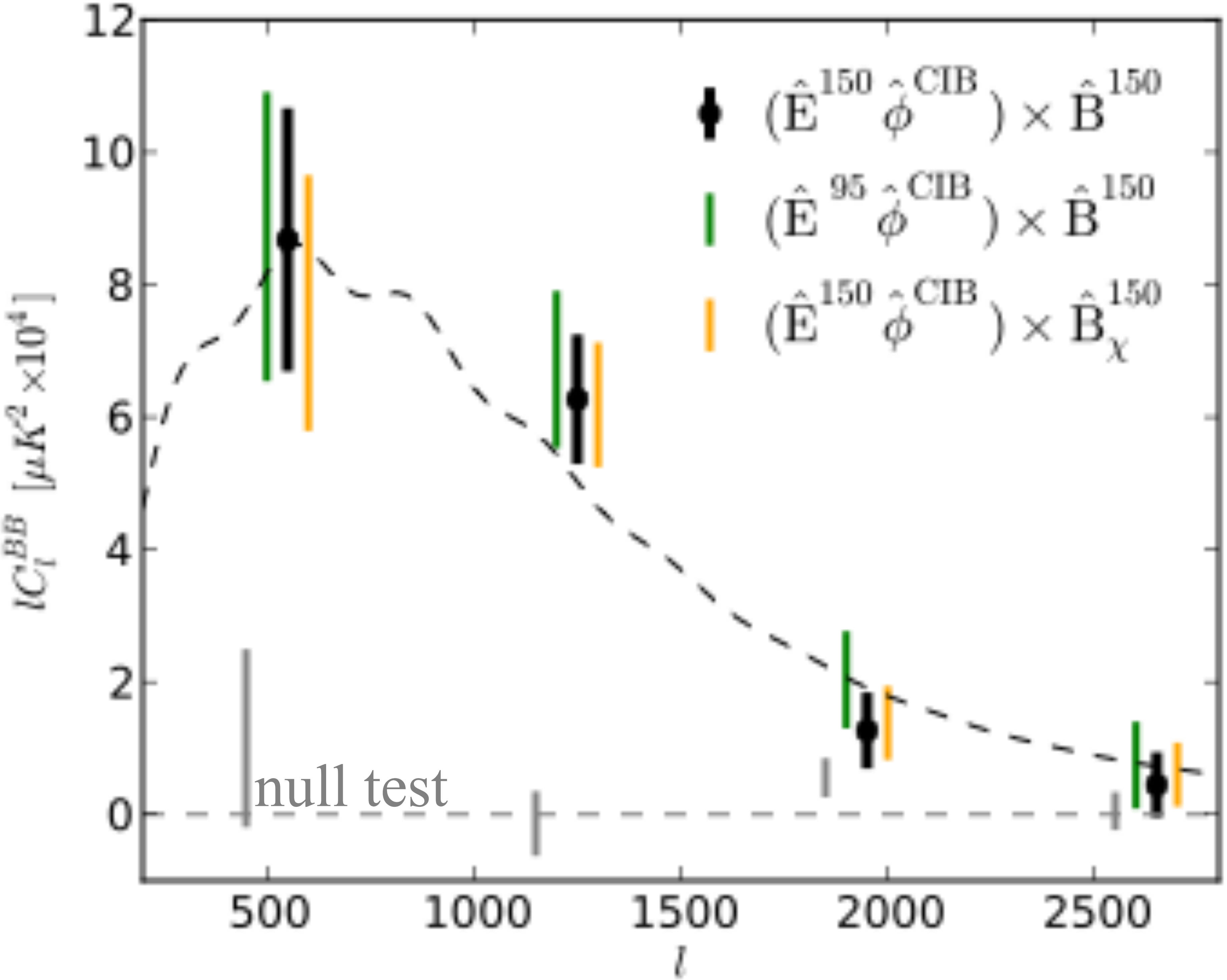
(presented by Hogan Nguyen)

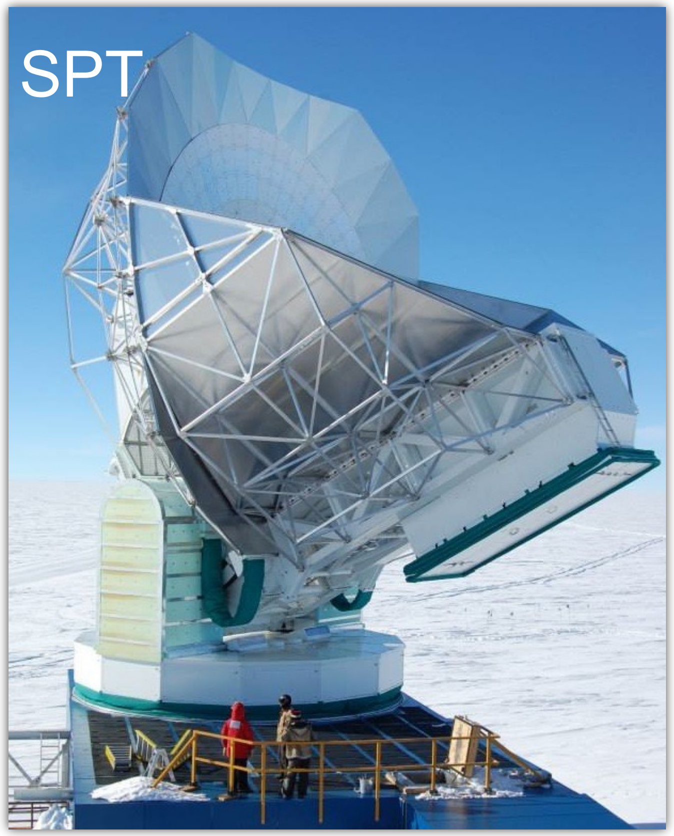
CMB Group at Fermilab:

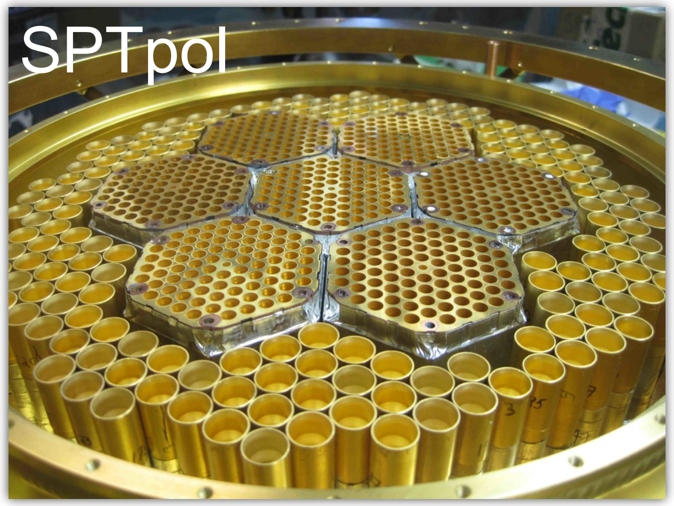
Brad Benson*, Donna Kubik, Hogan Nguyen,
Sasha Rahlin**, Adam Anderson**

* Group Leader
** Incoming RA/Lederman Fellow

Remarkable Progress on B-mode polarization:
July 2013: SPTpol Detection of Lensing B-modes

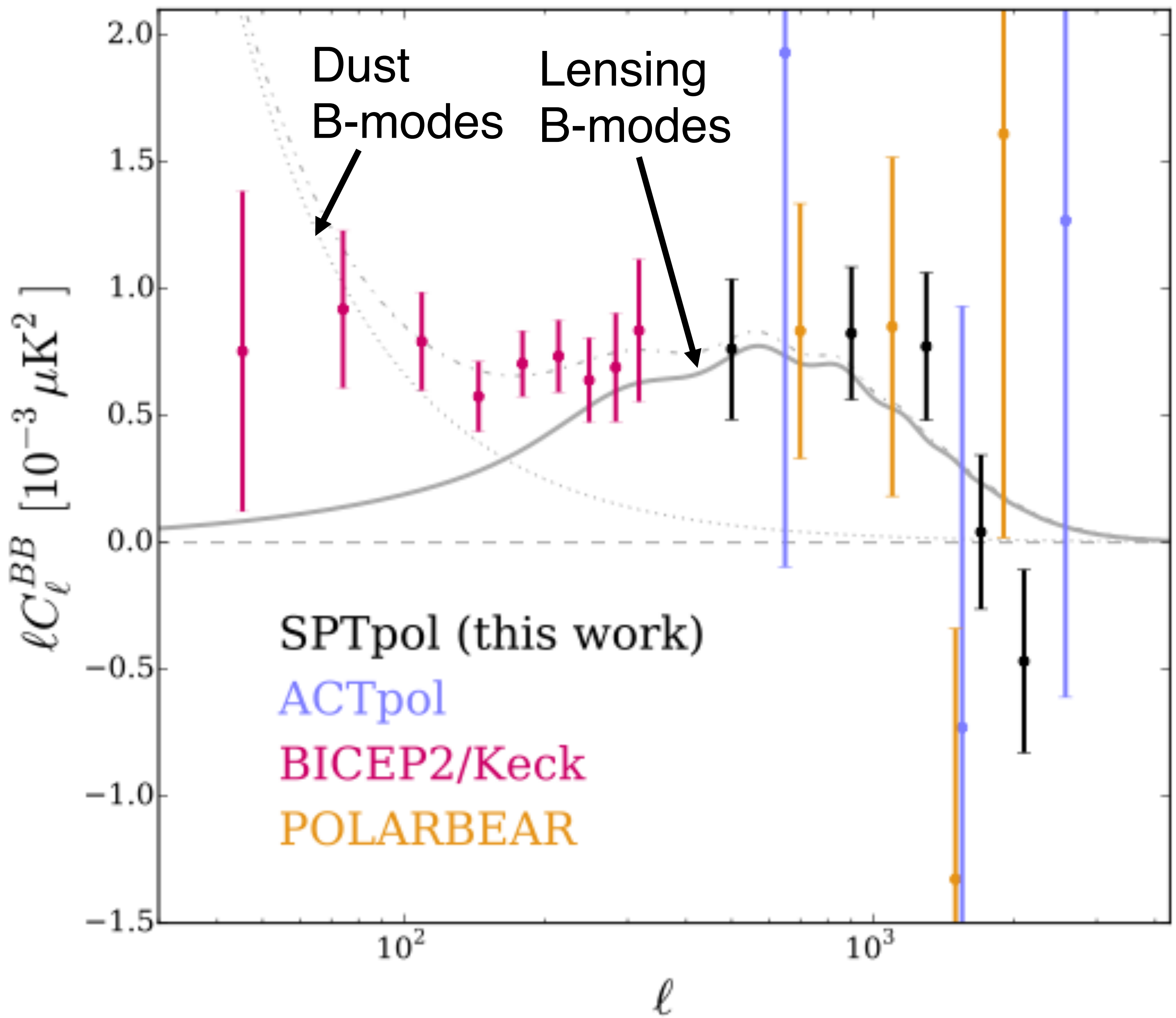






SPTpol: arXiv:1307.5830, 1411.1042, 1412.4760
Polarbear arXiv:1312.6645, 1312.6646, 1403.2369
BICEP2: arXiv: 1403.3985,1502.00612,1502.00643
ACTpol arXiv:1405.5524

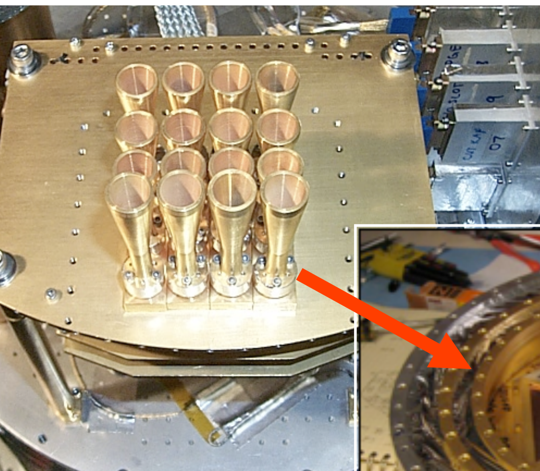
B-mode Power Spectrum Compilation



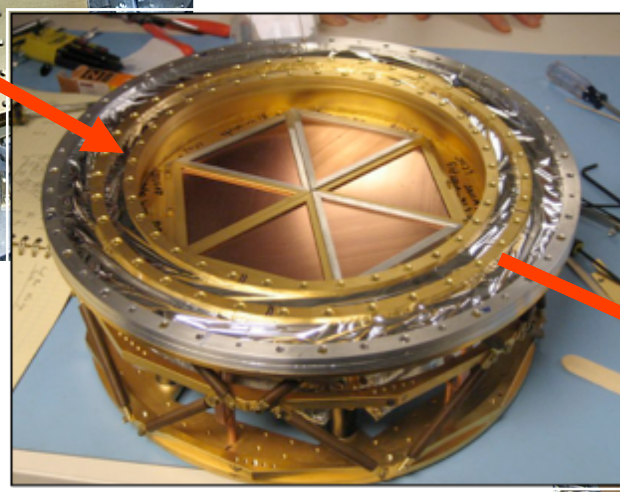
(SPTpol) Keisler et al. (2015, arXiv: 1503.02315)
(BICEP2/KECK x Planck collaborations) arXiv: 1502.00612

Evolution of CMB Focal Planes

2001: ACBAR
16 detectors

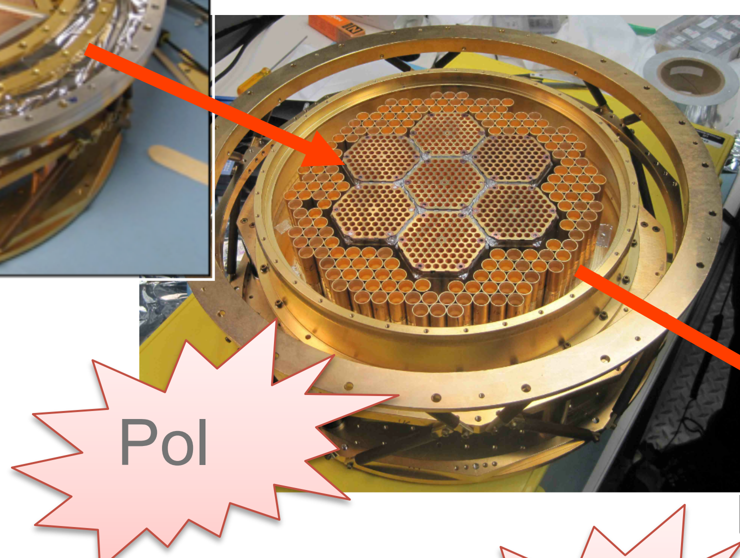


2007: SPT
960 detectors

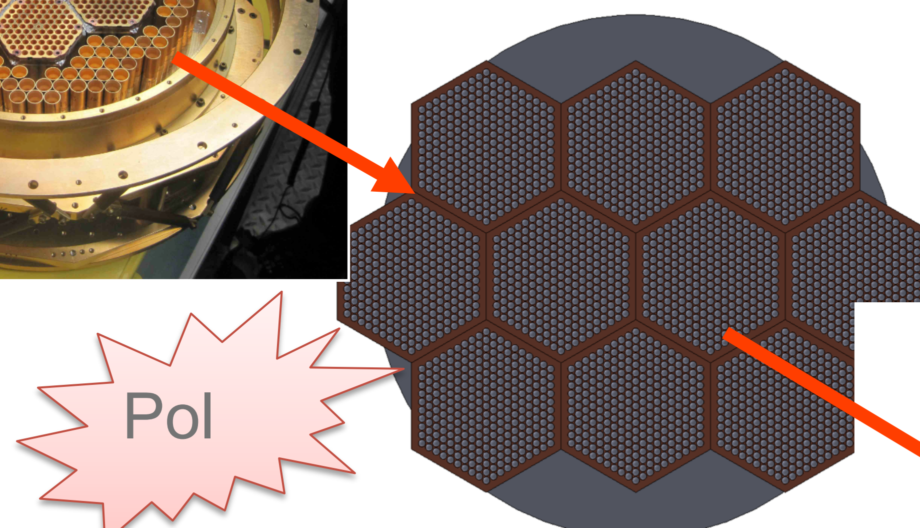


CMB Stage-4 Experiment
Described in Snowmass CF5:
Neutrinos: arxiv:1309.5383
Inflation: arxiv:1309.5381

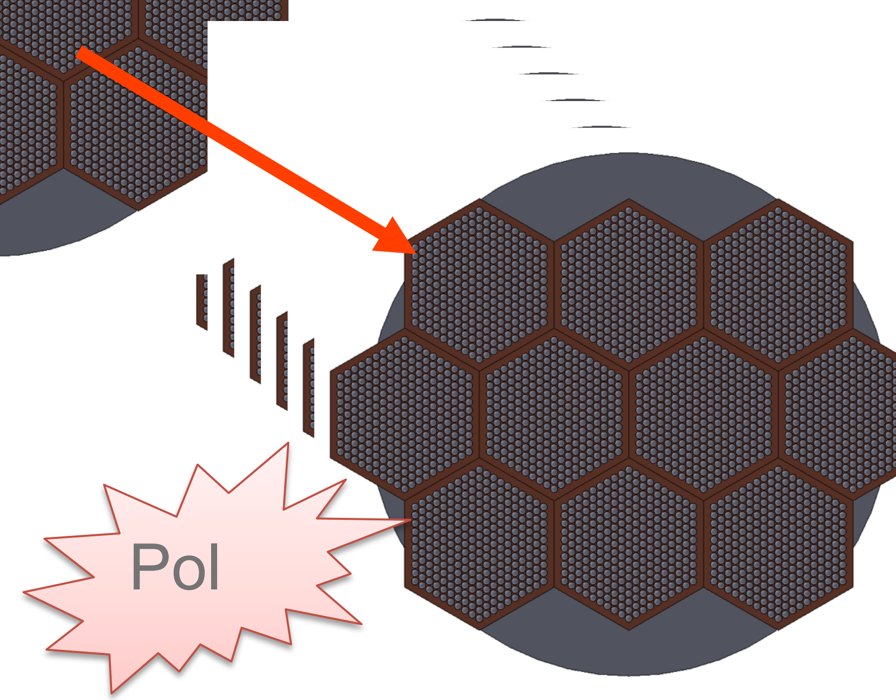
Stage-2
2012: SPTpol
~1600 detectors



Stage-3
2016: SPT-3G
~15,000 detectors

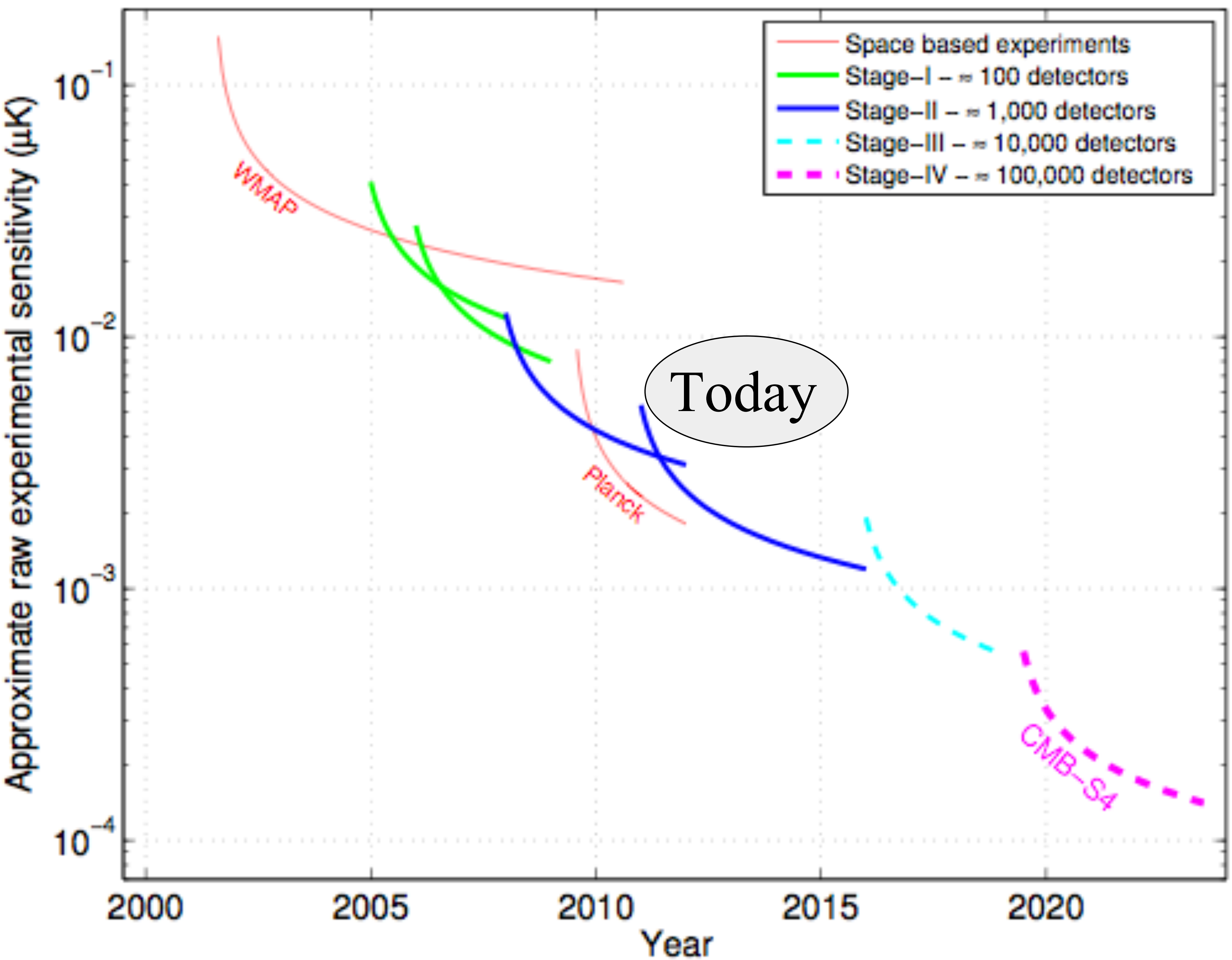


Stage-4
2020?: CMB-S4
200,000+ detectors



Detector sensitivity has been limited by photon “shot” noise for last ~15 years; further improvements are made only by making ***more detectors!***

CMB Experimental Stages

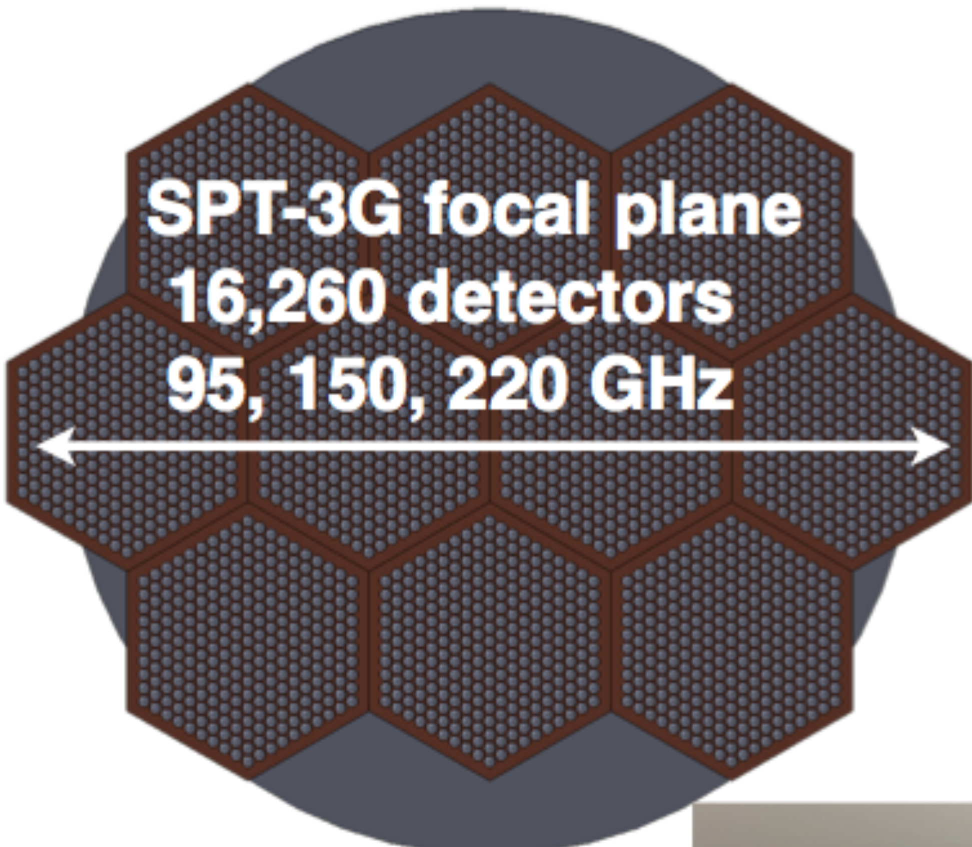


Stage-IV CMB experiment = **CMB-S4**

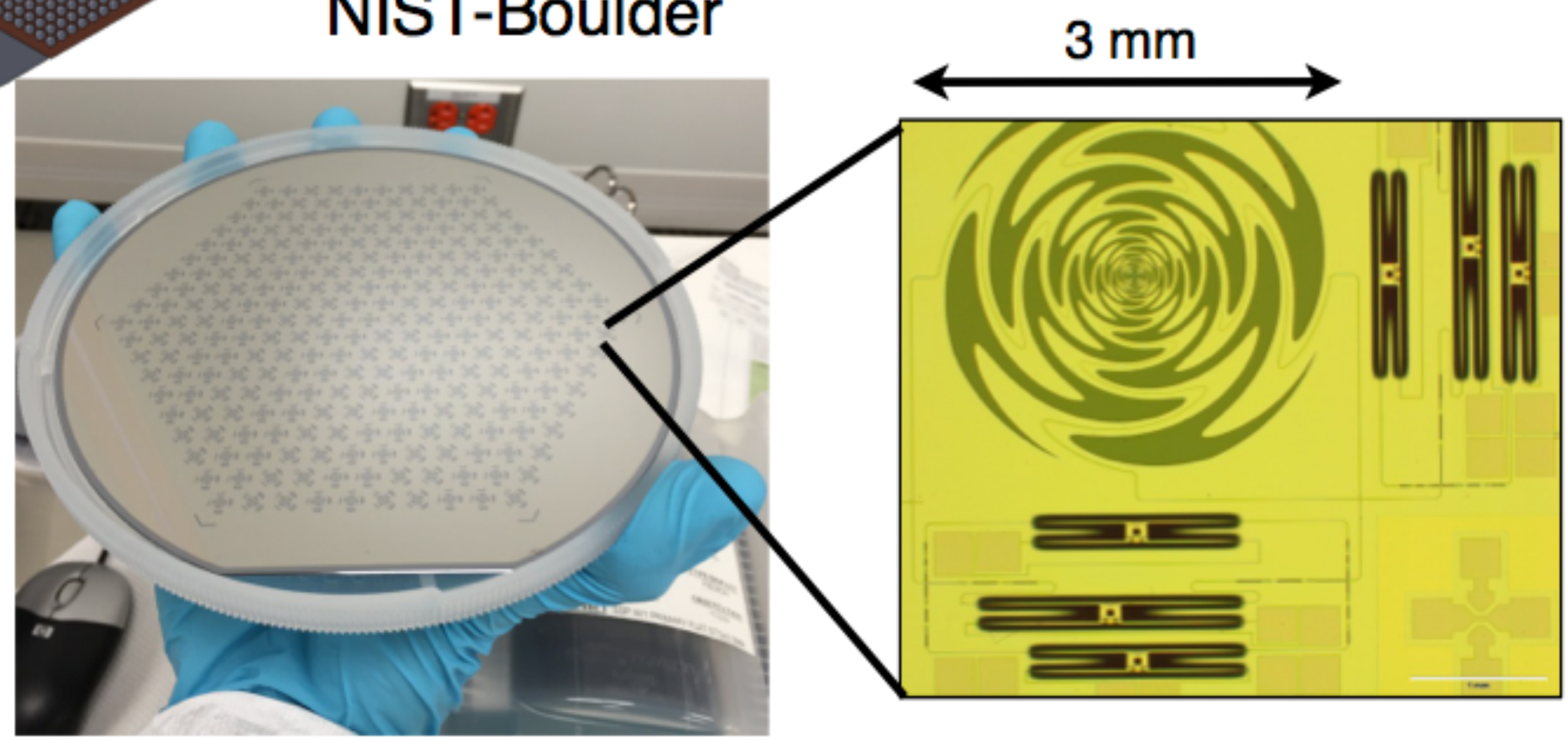
~200x faster than today's Stage 2 experiments

Snowmass: CF5 Neutrinos Document
arxiv:1309.5383

SPT-3G: 10x leap with multichroic pixels



- Using lenslet coupled, 3-band sinuous antenna coupled TES detector design from UCB (Suzuki et al, 1210.8256)
- Detector fabrication at Argonne National Labs on 6” silicon wafers led by C. Chang
- 68x frequency multiplexed SQUID readout (McGill), using SQUIDs from NIST-Boulder

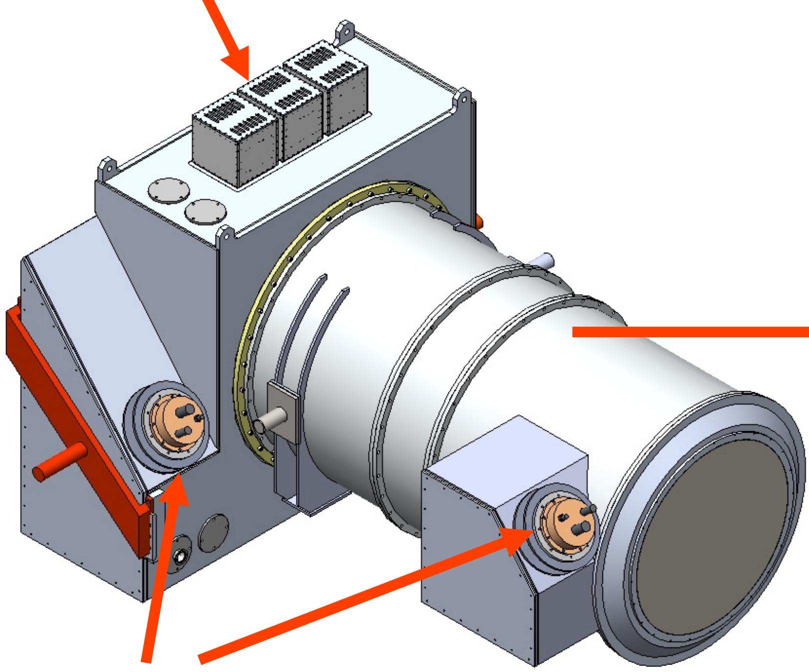


J. Carlstrom’s Fermilab Institutional Review talk, Feb 2015

CMB Activities at FNAL

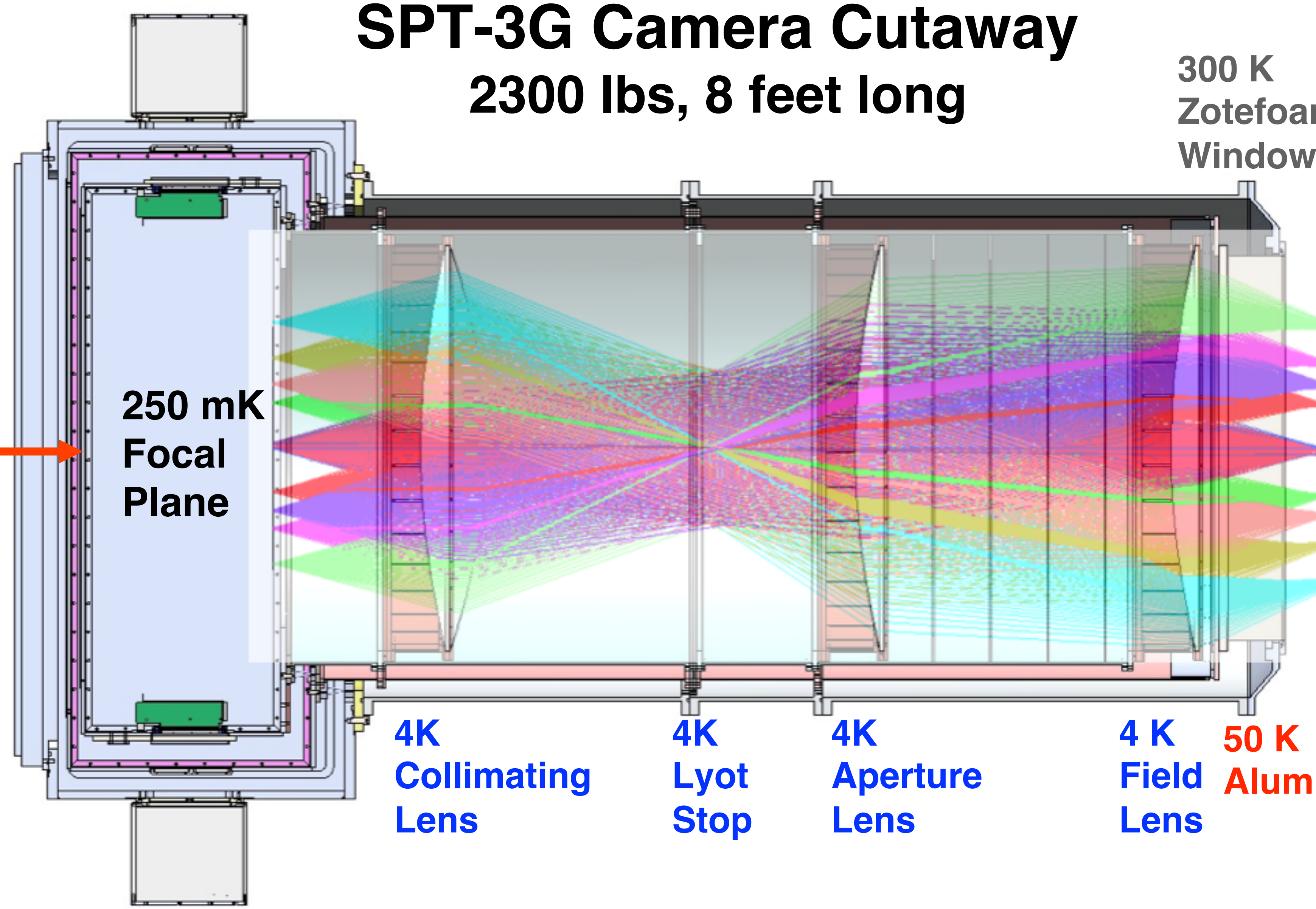
- **SPT-3G Camera:** Design and fabrication of cryostat, and integration with 250 mK detector focal plane.

SQUID Electronics
Readout for TES detectors; 68x frequency domain multiplexing



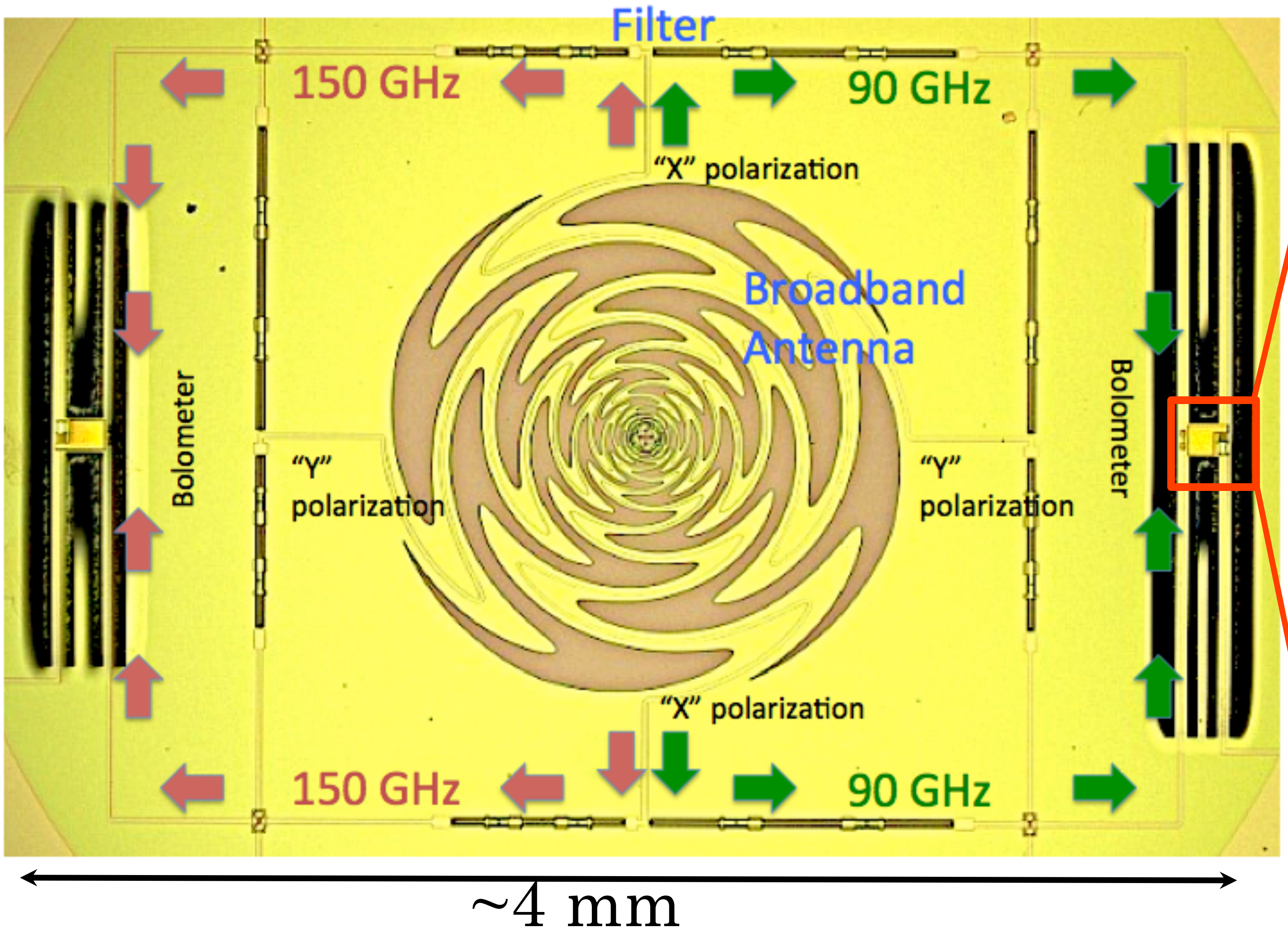
Pulse Tube Coolers
He4-He3-He3 fridge inside

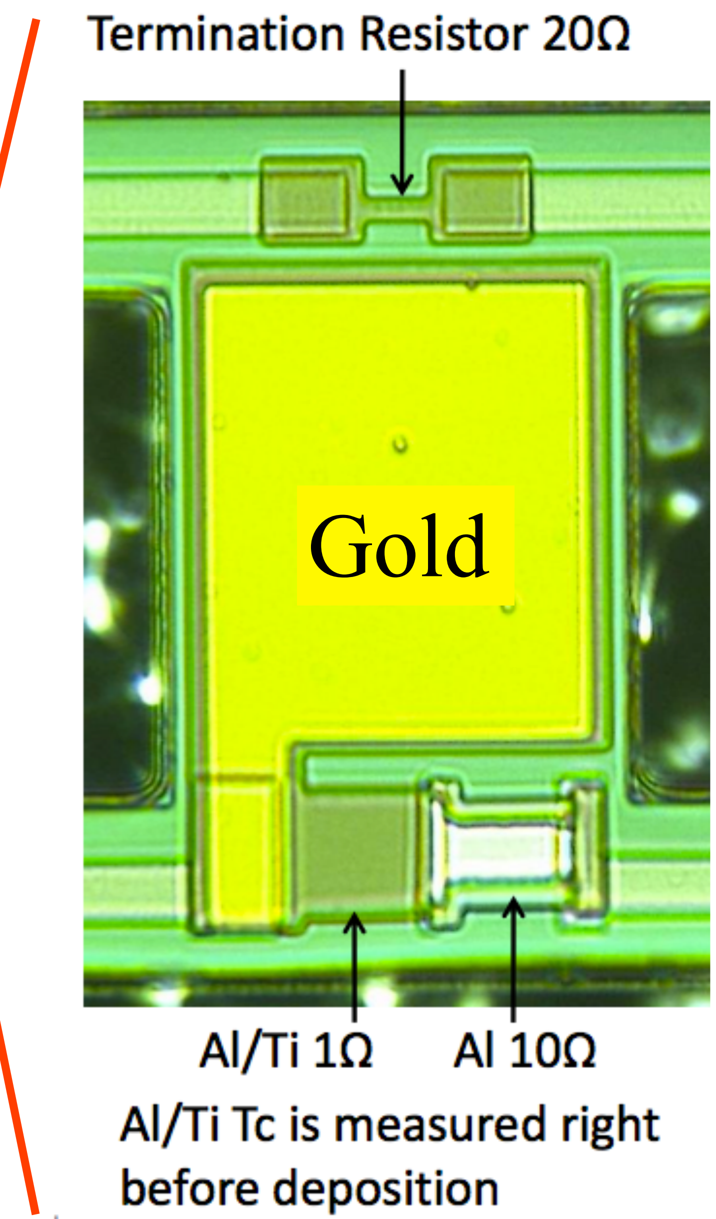
SPT-3G Camera Cutaway
2300 lbs, 8 feet long



CMB Activities at FNAL

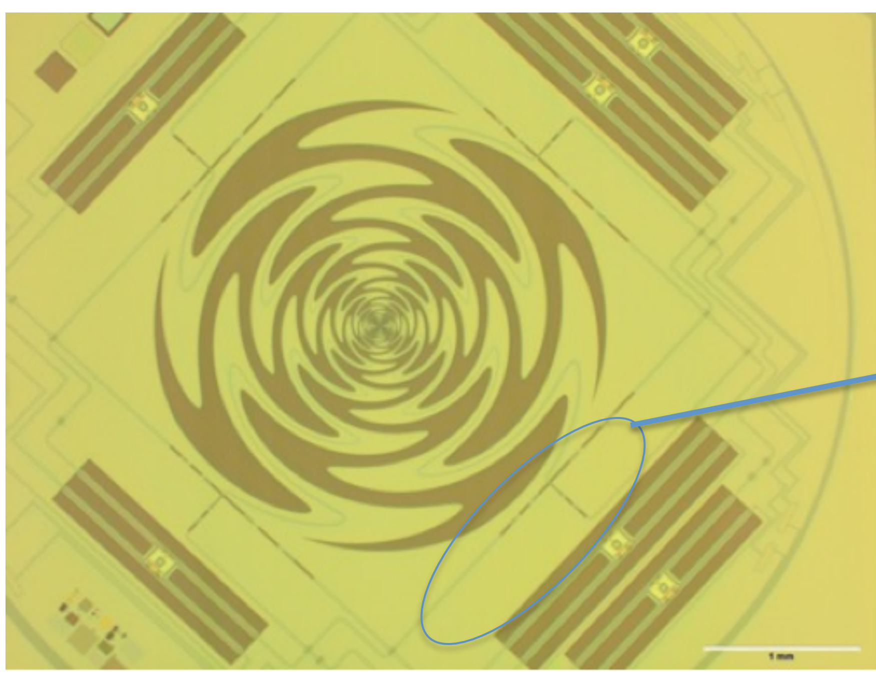
- **CMB Detector Design:** Prototype SPT-3G detector, a broadband sinuous antenna, coupled to inline Nb micro-strip, which terminate microwave power on a Ti transition edge sensor (TES).



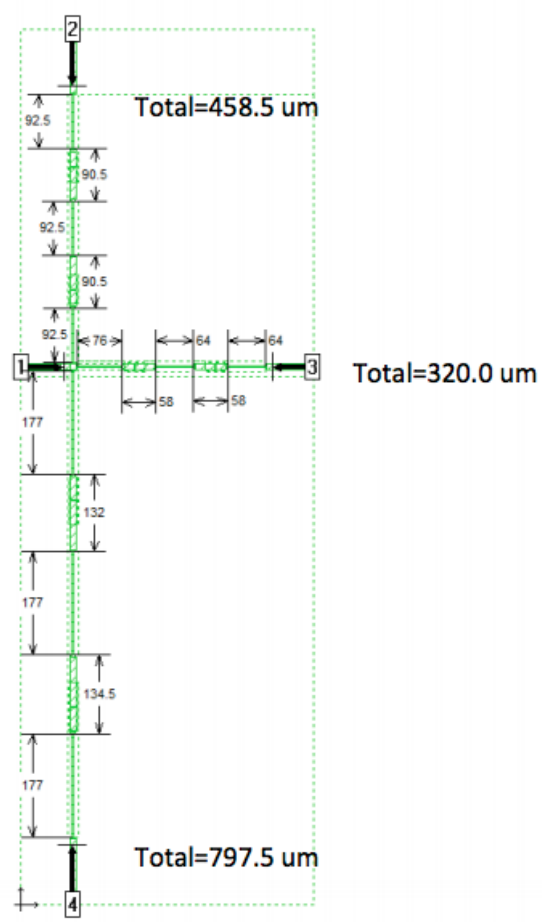


Sonnet®, a high-frequency electromagnetic simulation package, has been used to study the performance of the SPT-3G filter design

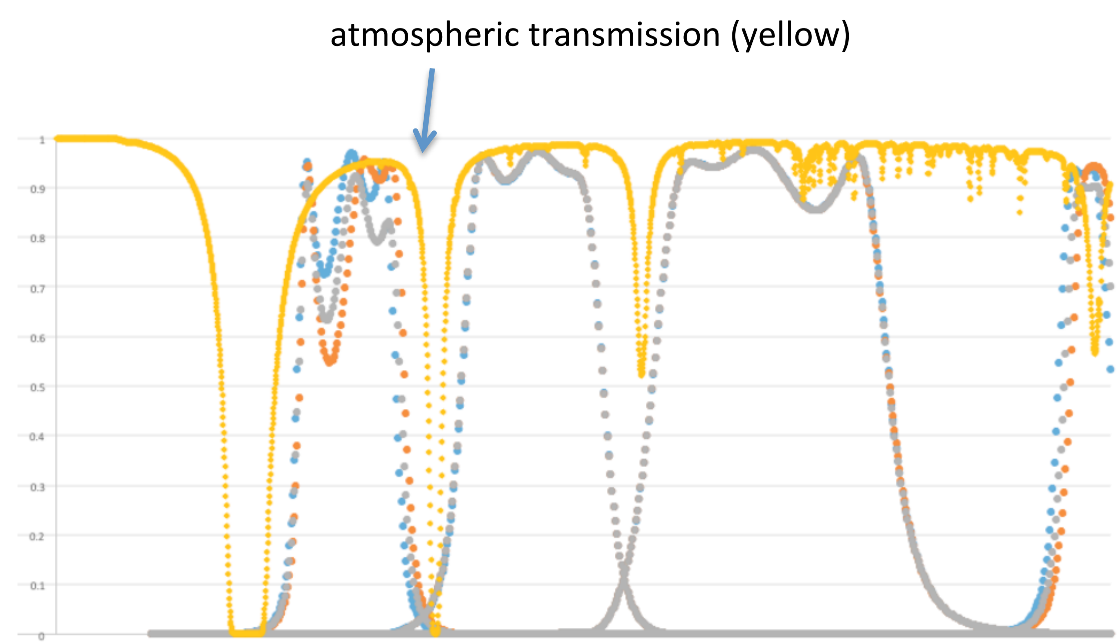
- Commissioned a new server at Fermilab, dedicated to Sonnet simulations (March, 2015)
- The more-powerful server facilitates more-detailed, more-accurate simulations.
- The simulation shown took 5.6 hours using the new server vs. 14.6 hours on the older server.
- SPT-3G hosted a one-day hands-on Sonnet at Fermilab (February, 2015).
- 17 Sonnet class attendees from SPT-3G and MKIDs (FNAL, ANL, and University of Chicago)



SPT-3G pixel

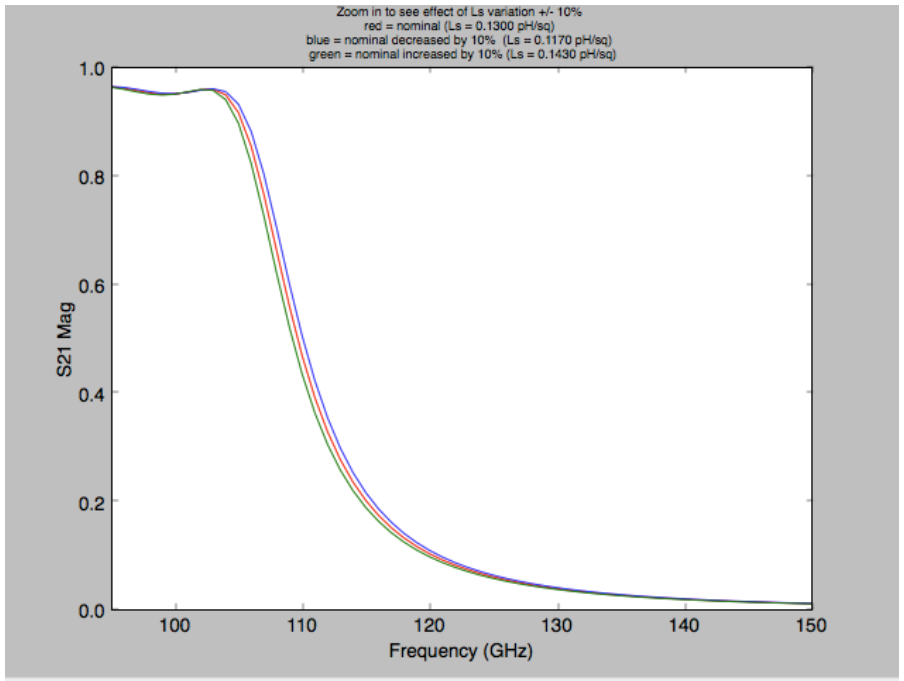


Sonnet geometry for filter

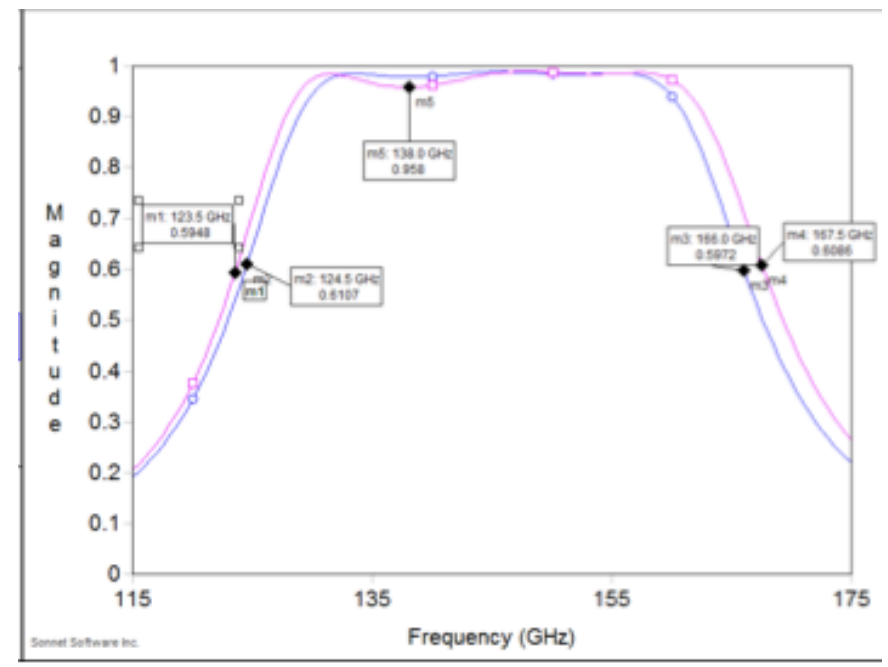


Sonnet simulation result showing filter transmission vs. function and how it fits within the atmospheric transmission bands

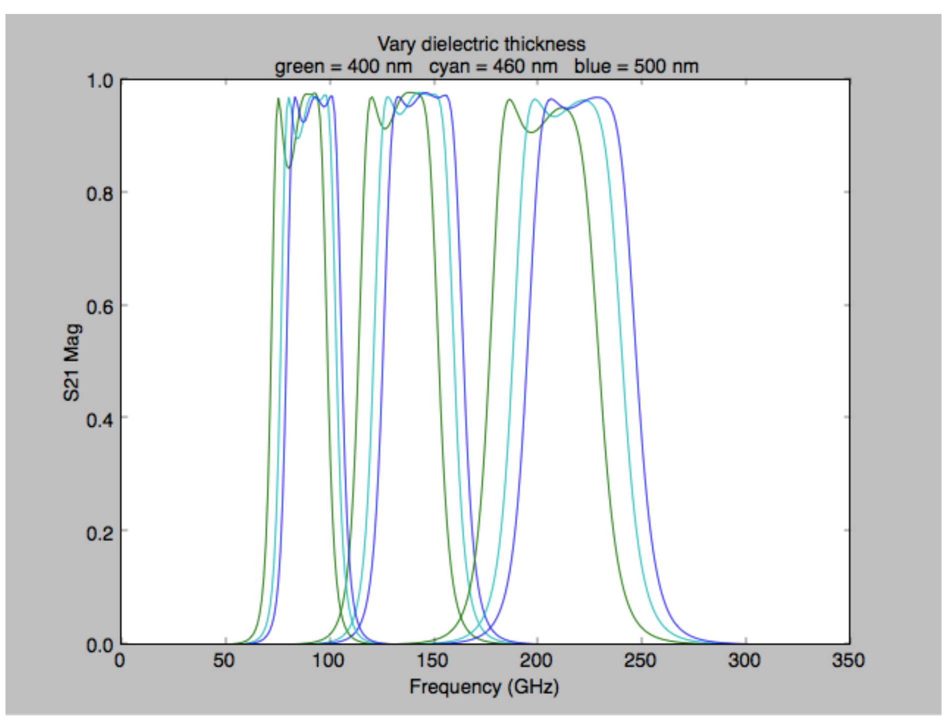
Sonnet® simulations studied the effect of material properties and fabrication tolerances which showed the design is robust



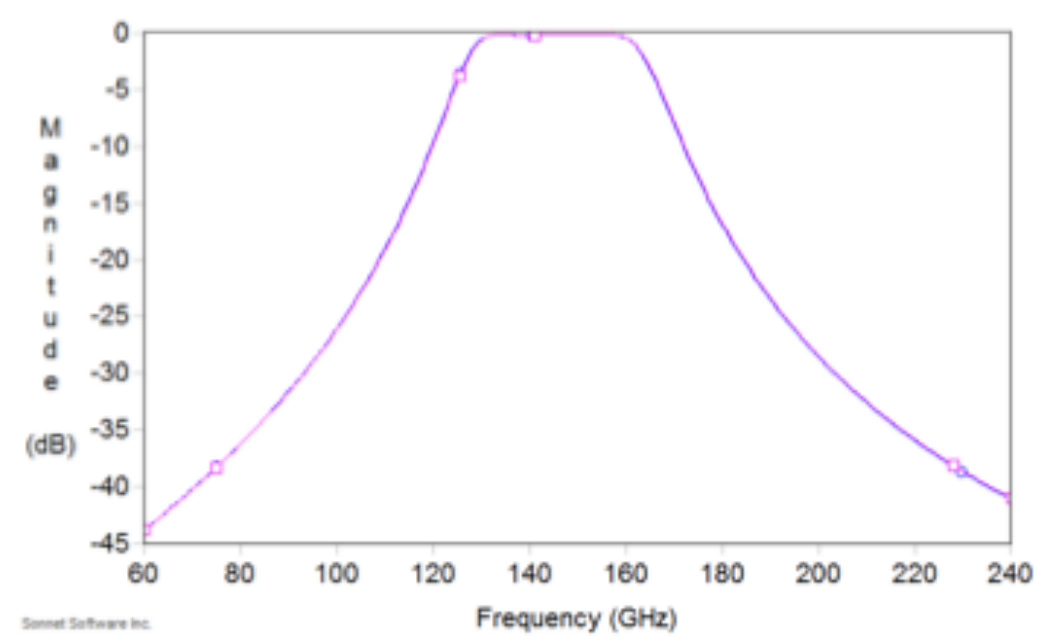
Tolerant to changes in kinetic inductance



Tolerant to over-etching

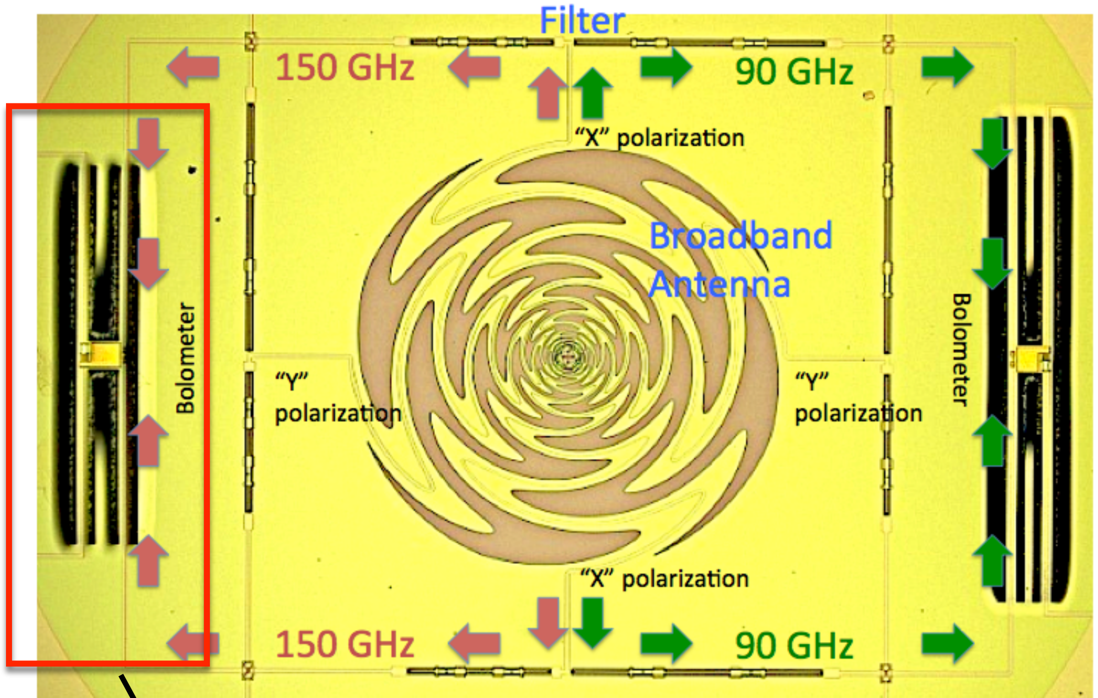


Vary dielectric thickness

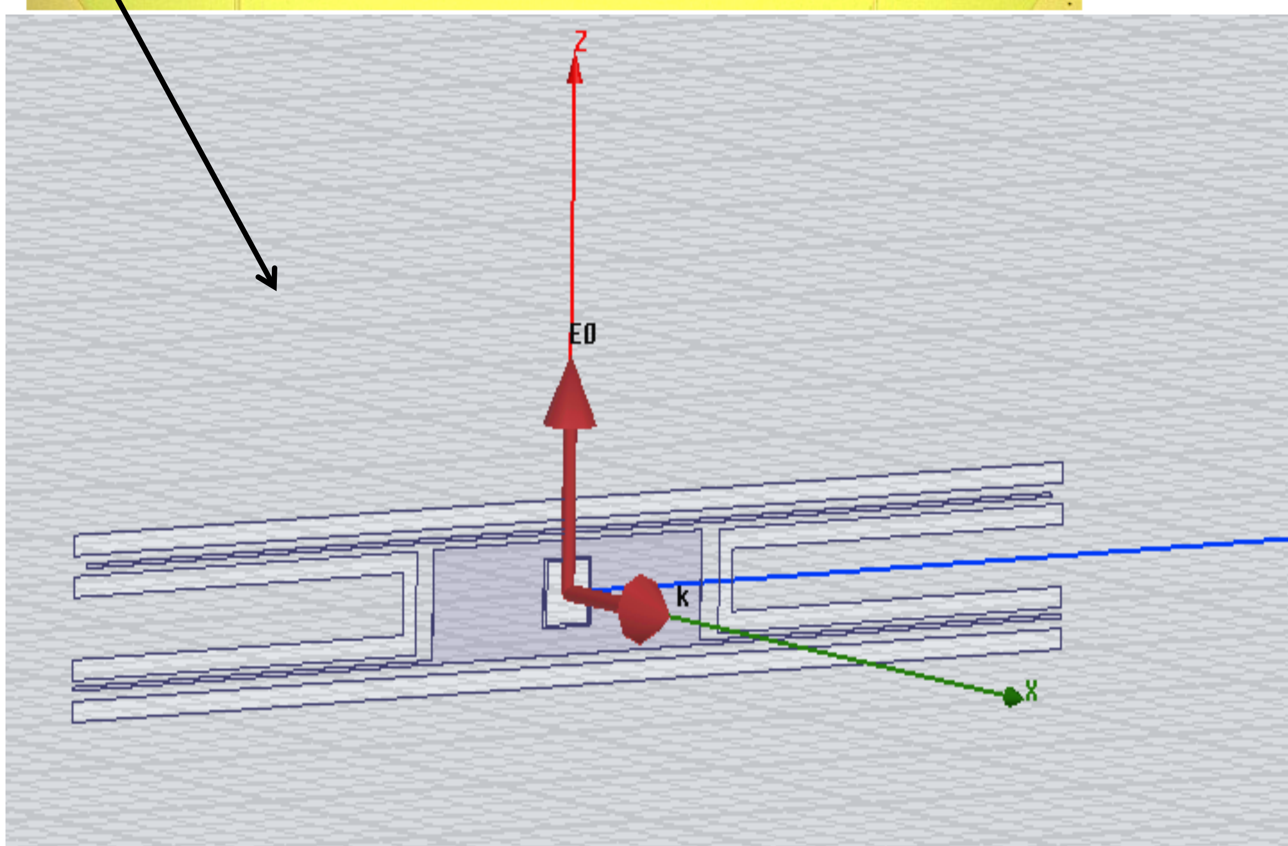


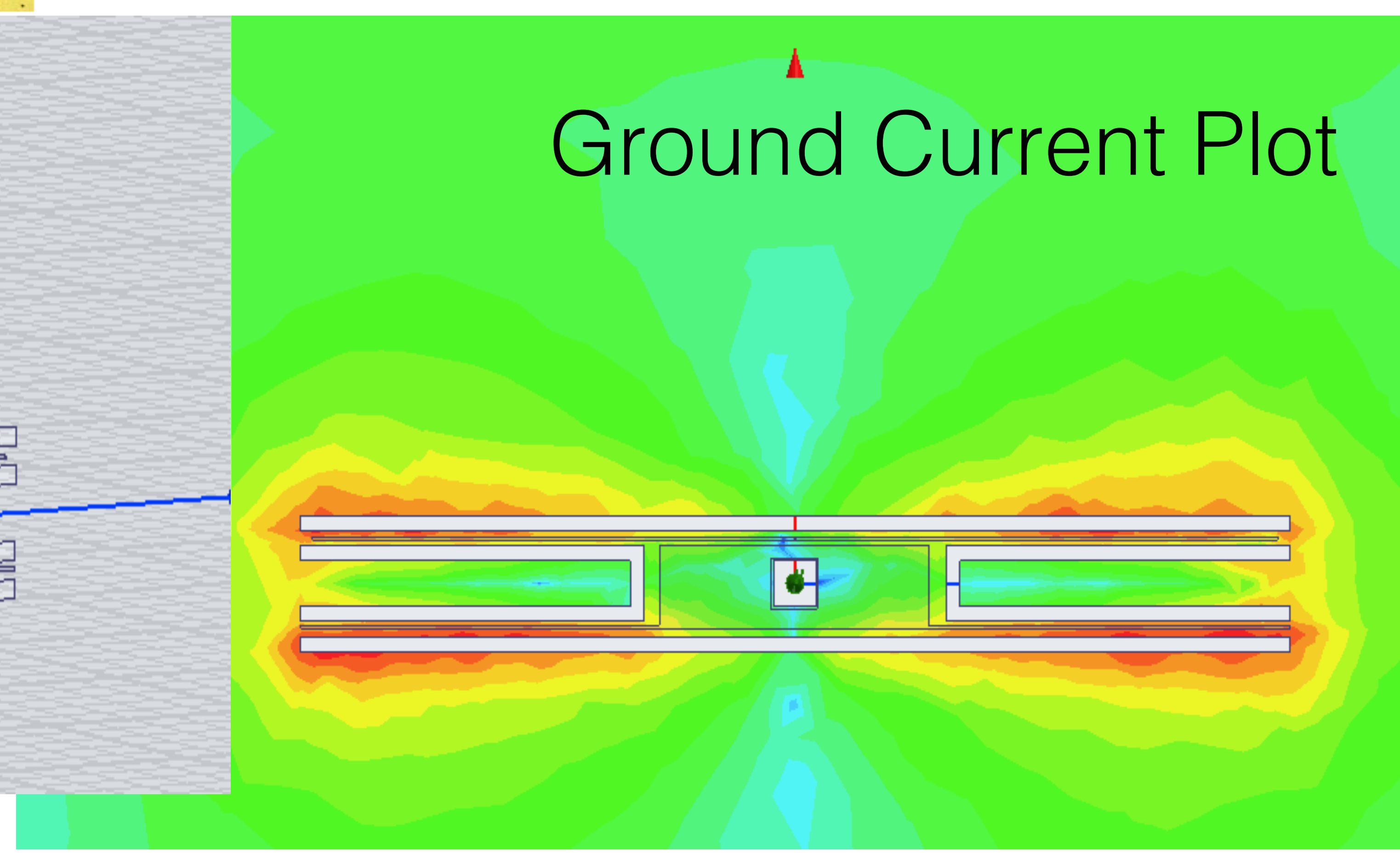
Tolerant to registration offsets

CMB Activities at FNAL



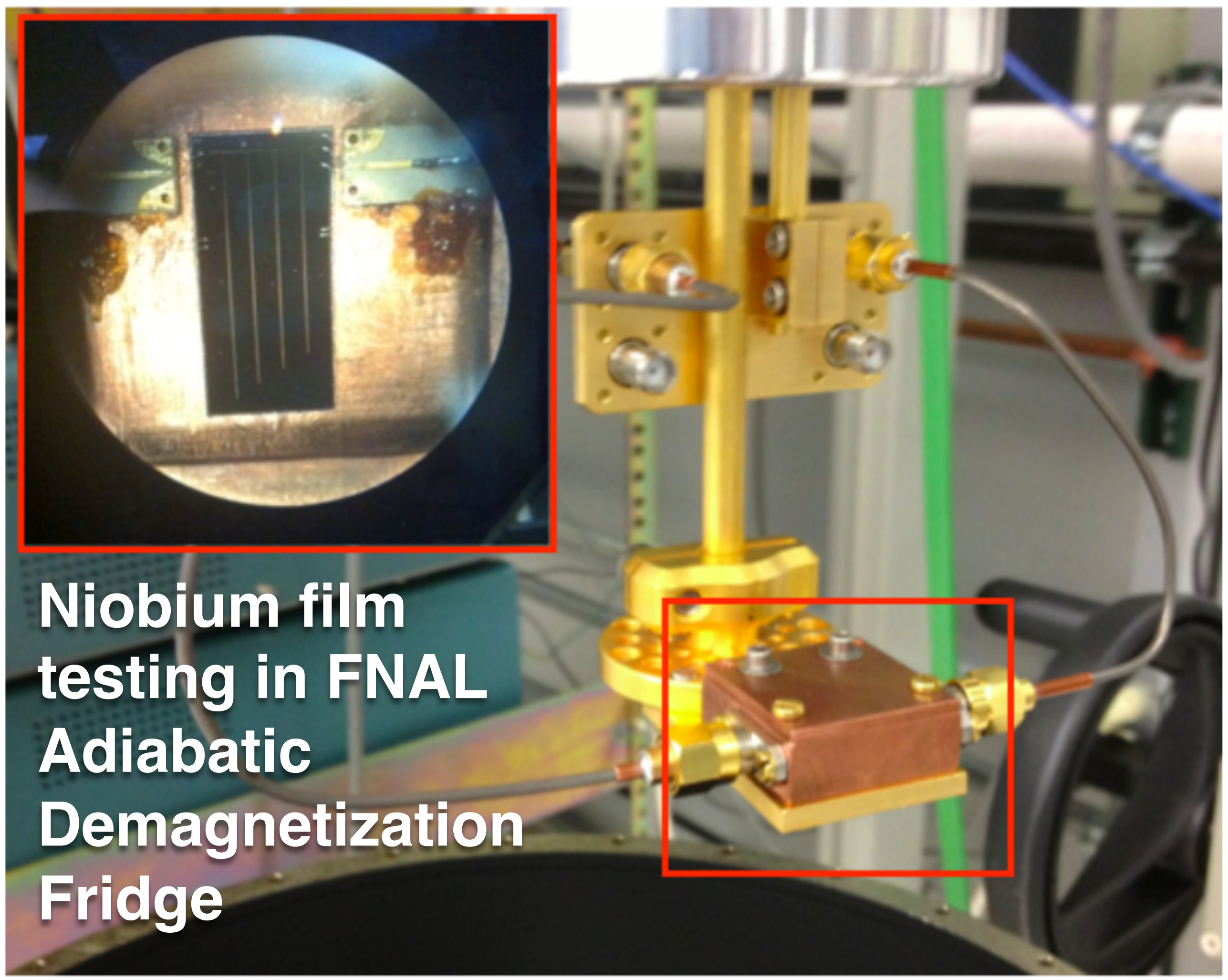
RF Simulations of
TES Island to Minimize
Dark Pickup

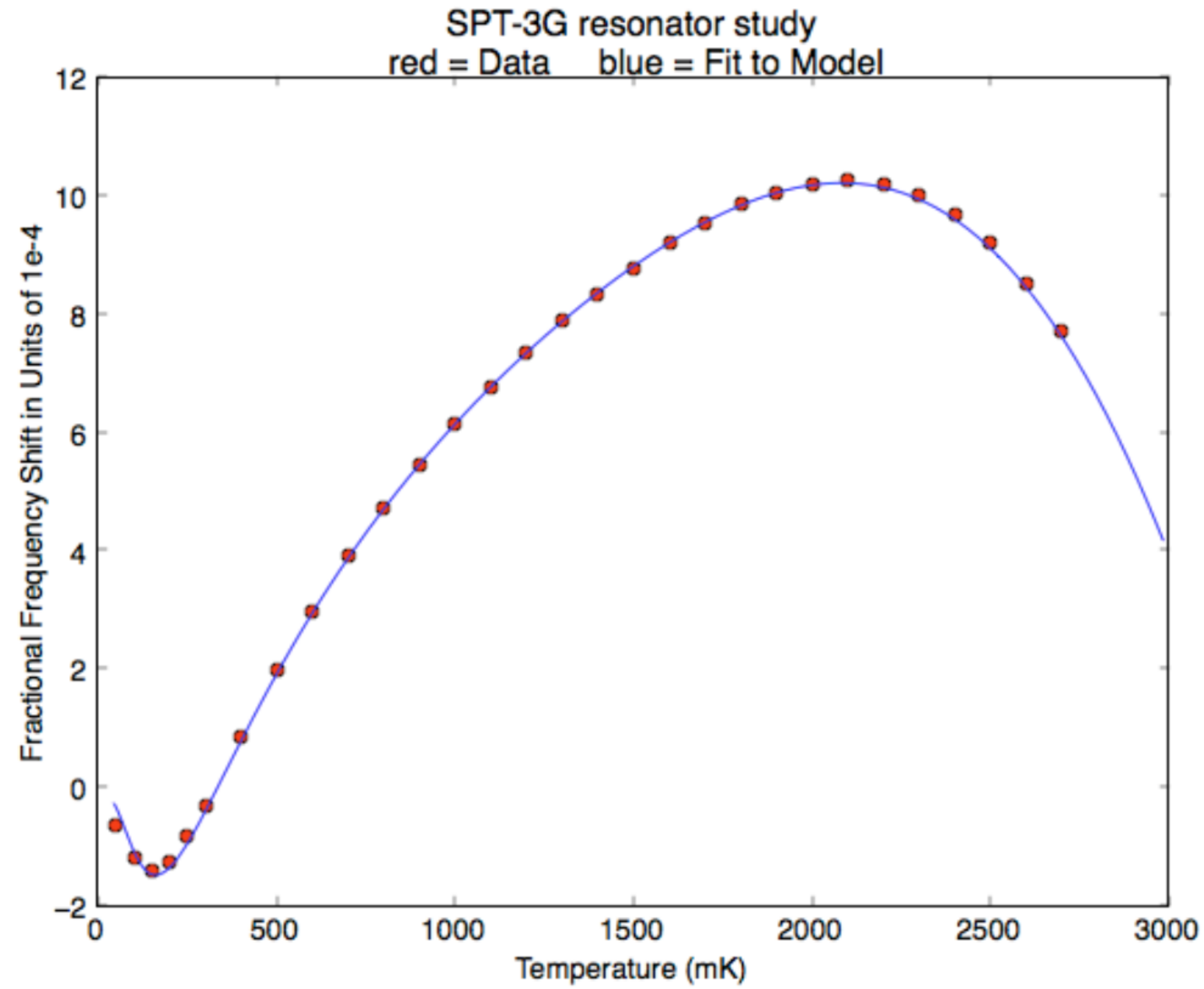




CMB Activities at FNAL

- **Characterize Superconducting Microstrip:** Measure resonance in Nb microstrip from 50 - 3000 mK to characterize loss over CMB signal band from 40-300 GHz.



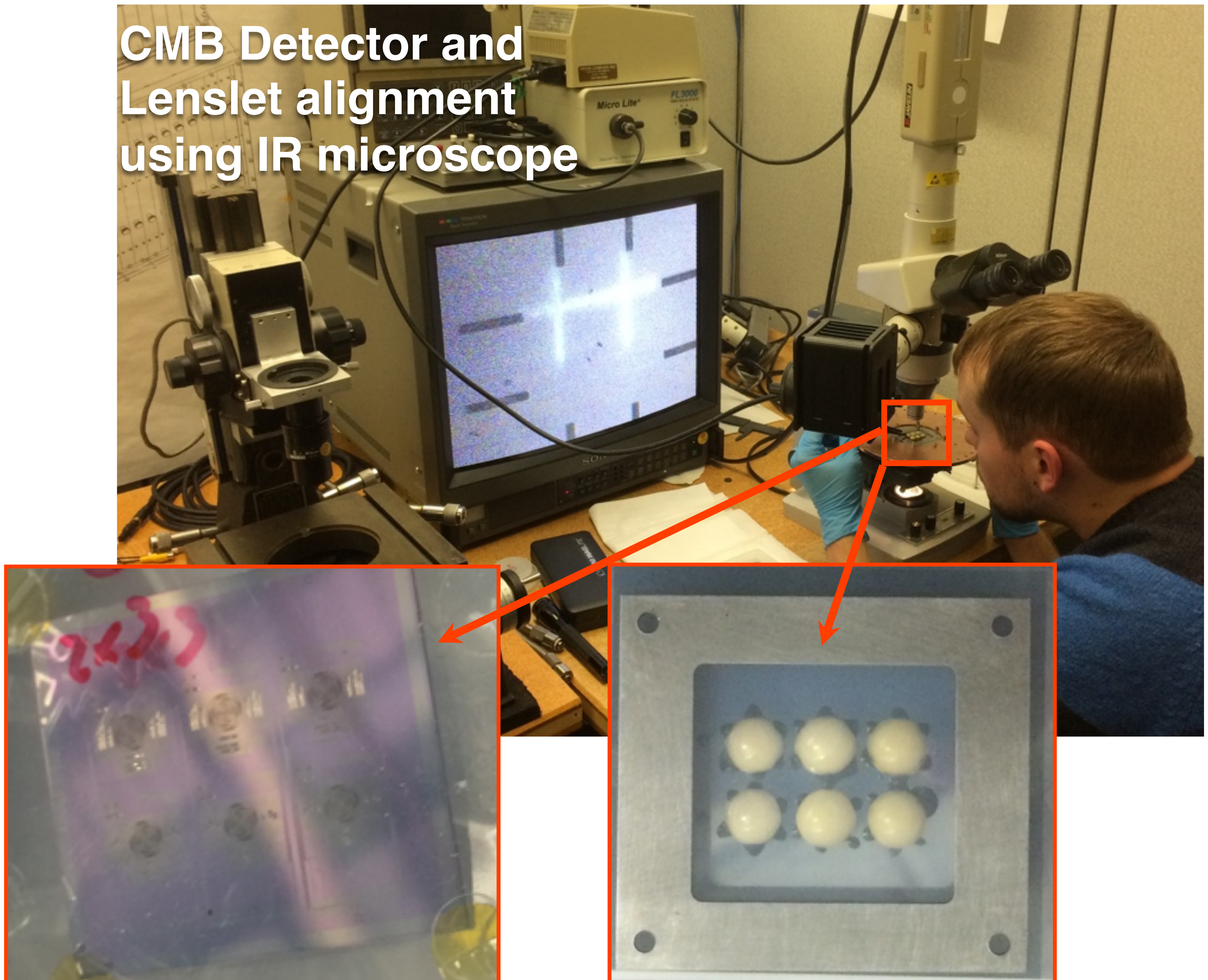


CMB Activities at FNAL

- **CMB Detector Characterization:** New PTC backed He3 fridge system at SiDet, designed to simultaneously test ~5000 TES detectors.

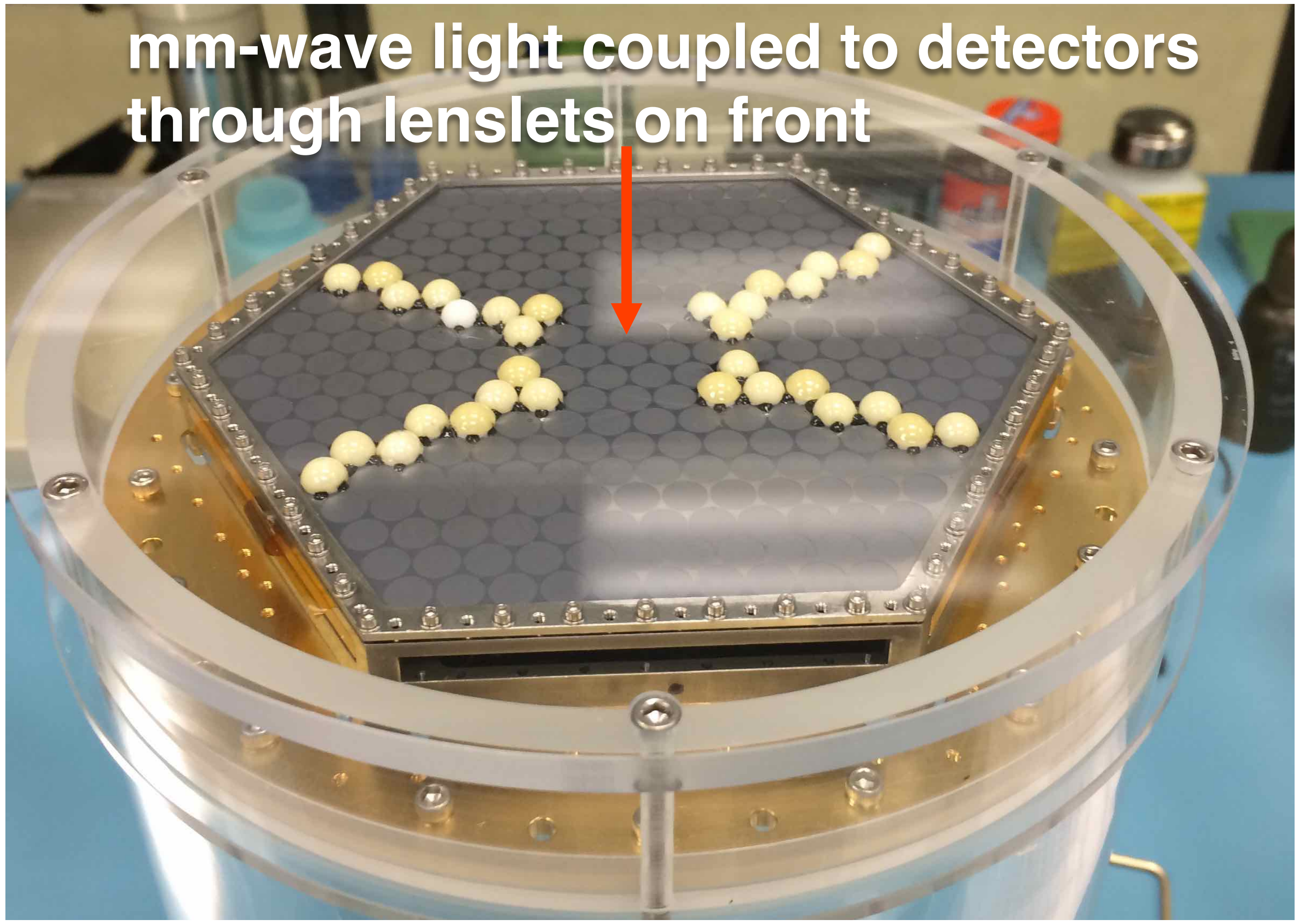
CMB Activities at FNAL

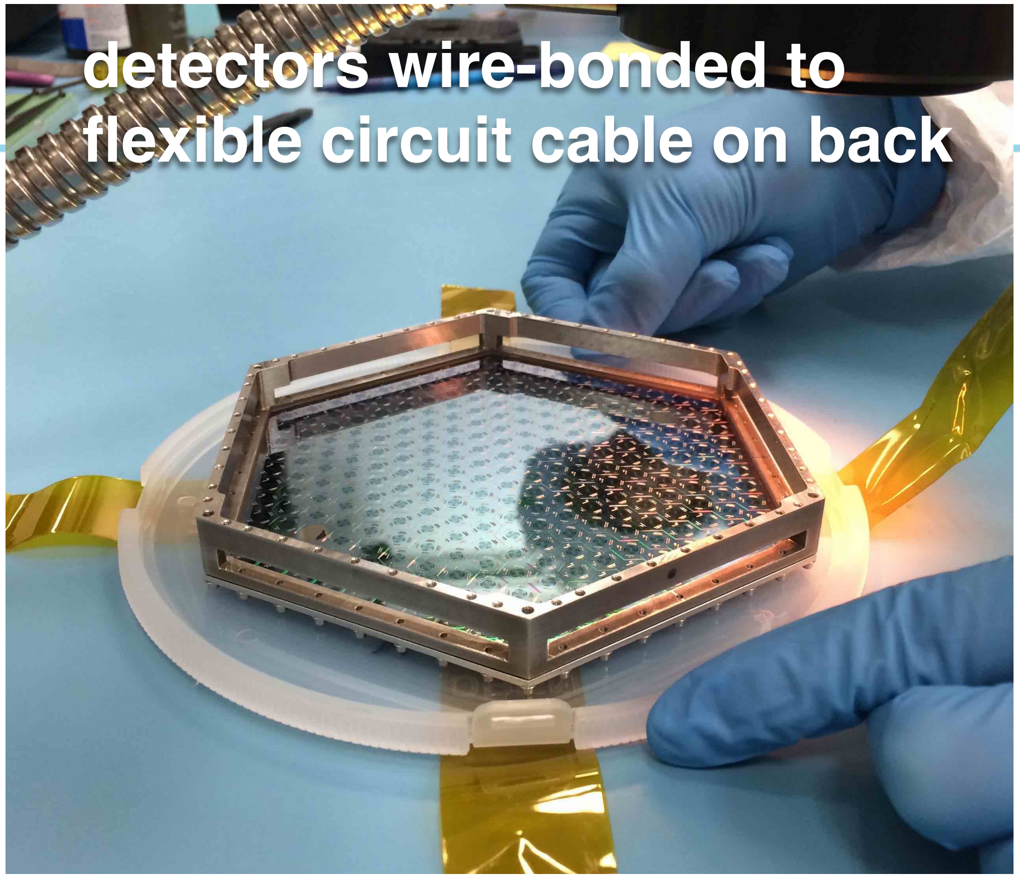
- **CMB Detector Wafer Alignment:** Achieve alignment of CMB detector arrays with matching alumina lenslet array with 10 micron precision.

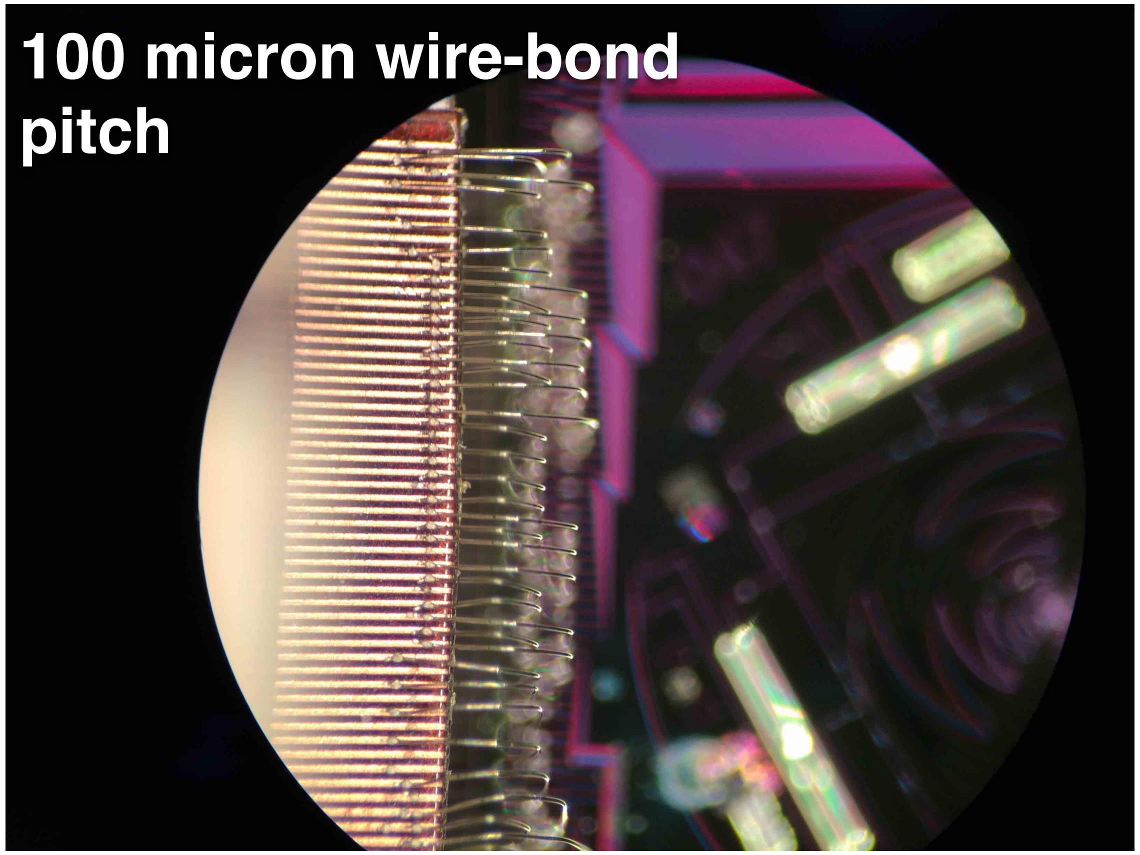


CMB Activities at FNAL

- **CMB Detector Wafer Packaging:** Assemble and wire-bond detector arrays with 1600 TES's and 3200 wire-bonds per wafer (10 wafers in SPT-3G focal plane).







Summary

LDRD Activity Builds on Fermilab Experience with HEP silicon VTX detectors and the DES Camera:

Developing Concepts and Techniques for High Through-put Detector Assembly and characterization needed for a Stage-IV CMB experiment

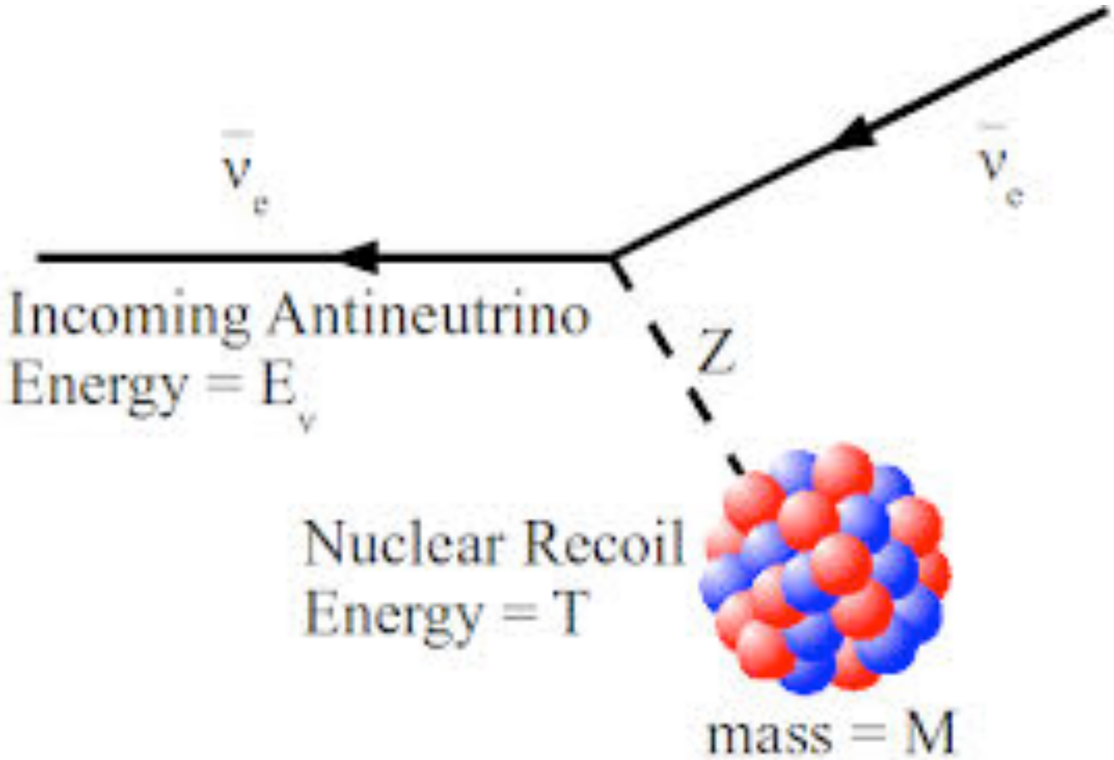
Material Testing and Characterization of SC materials at sub-K, and RF simulations

An intellectually vibrant effort in collaboration with many Institutions, including ANL, Berkeley, U of Chicago, U of Colorado/NIST

COHERENT NEUTRINO NUCLEUS
INTERACTION EXPERIMENT

Juan Estrada (PI)
Gustavo Cancelo (co-PI), Javier Tiffenberg (co-PI)

Coherent Neutrino Nucleus Scattering:



$$\frac{d\sigma}{dT_A} = \frac{G_F^2}{4\pi} m_A [Z(1-4\sin^2\theta_W) - N]^2 \left[1 - \frac{m_A T_A}{2E_\nu^2}\right]$$

At low recoil energies (T_A) the cross section is enhanced by $\sim N^2$. This process has not been measured yet…

WHAT IS NEEDED TO SEE THIS PROCESS?

- Strong source of low energy neutrinos:

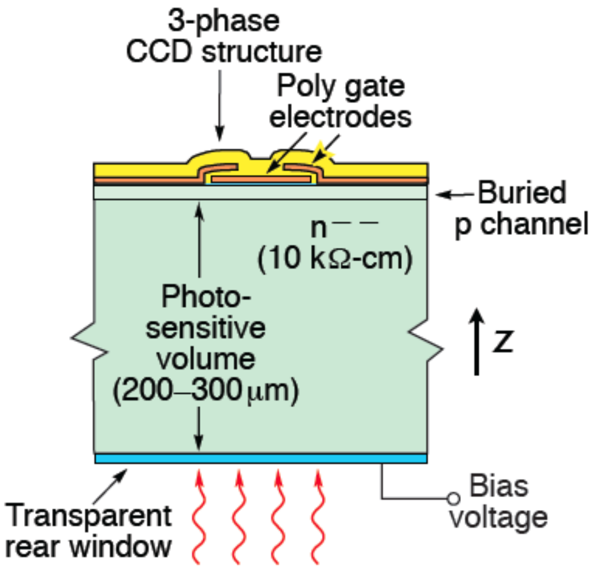
  A nuclear Reactor.

- Detector that can see very low energy nuclear recoils:

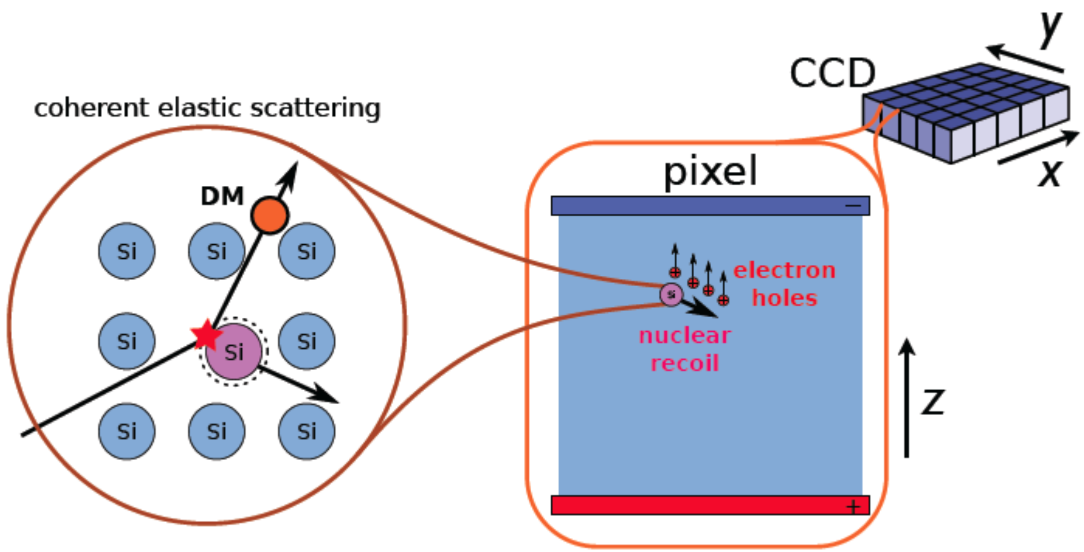
  Low threshold Dark Matter Detector (like DAMIC).

THE DETECTOR

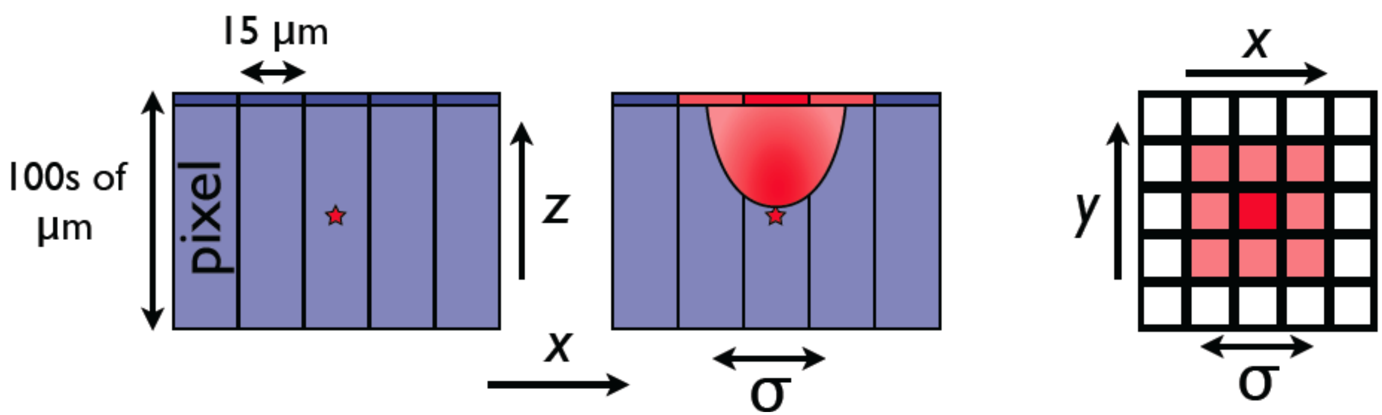
CCD detectors : DECam -> DAMIC -> now CONNIE



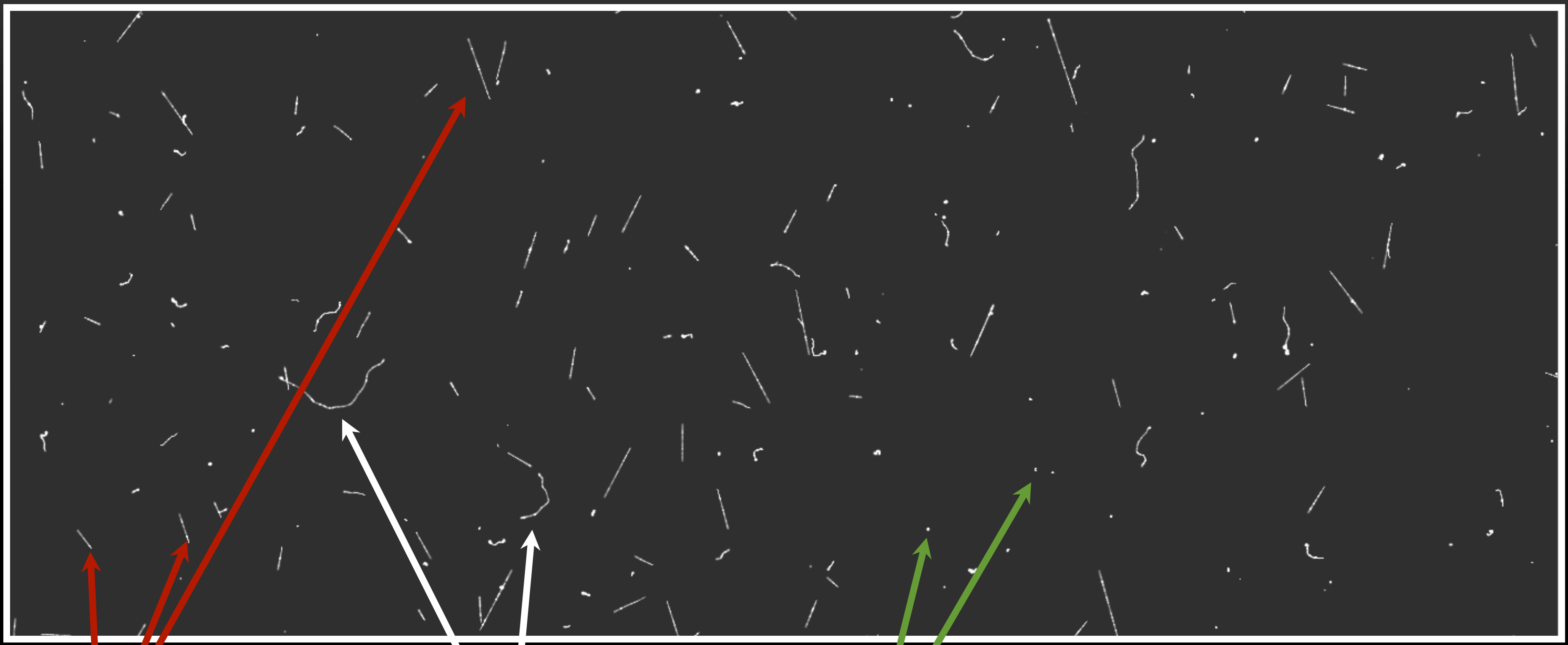
(a) A CCD pixel



(b) WIMP detection principle



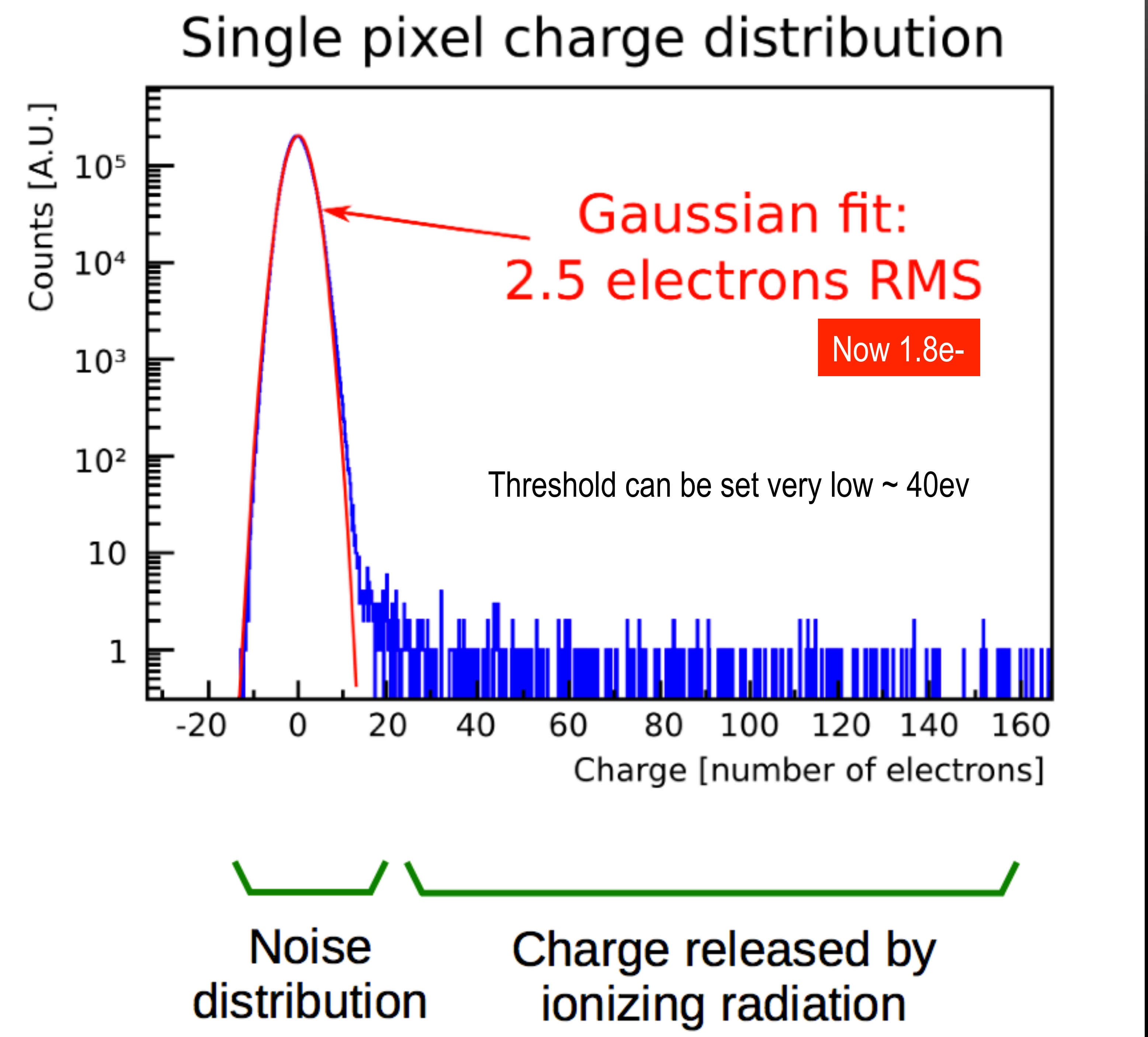
Particle identification in a CCD image



muons, electrons and diffusion limited hits.

Nuclear recoils will produce diffusion limited hits. Neutrinos from reactor are expected to produce nuclear recoils at a rate of 10,000 per day for each kilogram of detector.

arXiv:1408.3263


Single pixel charge distribution
Counts [A.U.]
10⁵
10⁴
10³
10²
10
1
-20
0
20
40
60
80
100
120
140
160
Charge [number of electrons]
Gaussian fit:
2.5 electrons RMS
Now 1.8e-
Threshold can be set very low ~ 40ev
Noise distribution
Charge released by ionizing radiation

THE SOURCE

Provided by our Brazilian collaborators.

In steady-state operation, the neutrino flux produced by the reactor is $1.21 \times 10^{20}\, \bar{\nu_e}/\mathrm{s}$ approximately, and the flux density at the detector (L = 30 meters from the core) is $7.8 \times 10^{12}\, \bar{\nu_e}/\mathrm{cm}^2/\mathrm{s}$. These large numerical values justify the use of nuclear reactors as neutrino source for the CONNIE experiment.

Our Collaborators in Brazil (CBPF and UFRJ) invited us to try this 30m from the core Angra-II power plant. Inside a conditioned shipping container.

EVENT RATE FOR CONNIE

assuming 52g detector array

Signal vents day (year)

E_{th}	$Q = 0.2$
$1\sigma_{RMS}$ (5.5eV)	1.46 (532)
$5\sigma_{RMS}$ (28eV)	0.94 (343)

Estimated
Bkg=8.5 ev/day

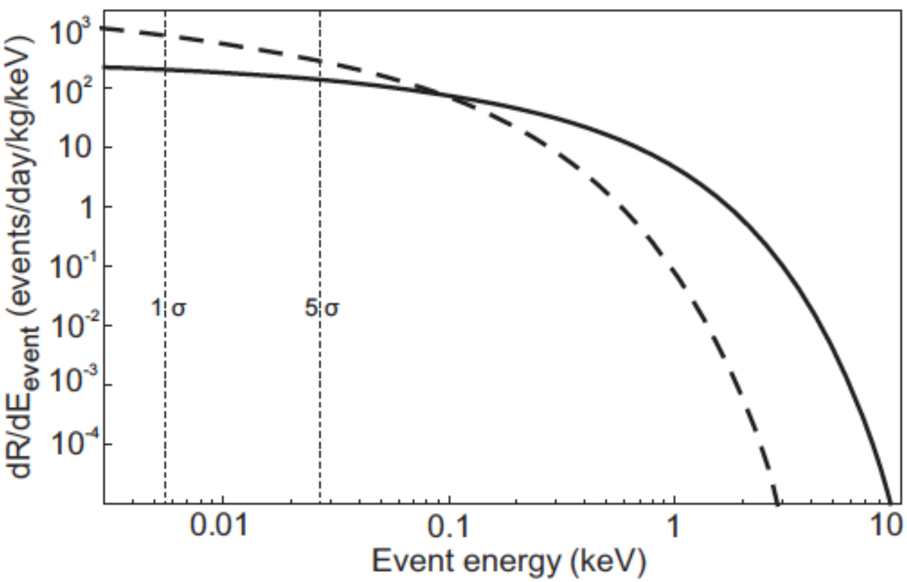


FIG. 8. Energy spectra for events expected in silicon detectors: the nuclear-recoil energy spectrum (—); the spectrum for detectable events (– –), using the quenching factor from Lindhand, *et al.* [28, 29].

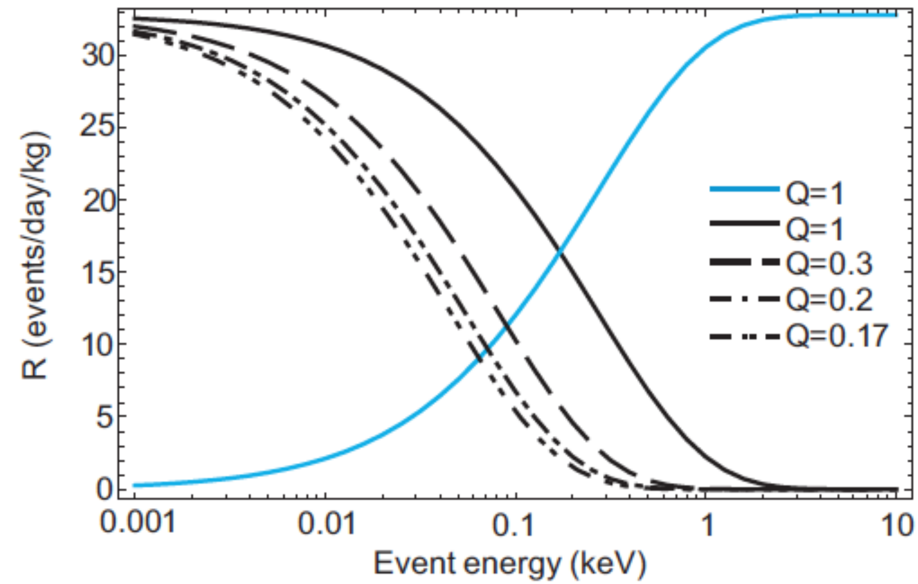


FIG. 9. Total number of events as a function of the threshold energy for different quenching factors: $Q = 1$, $Q = 0.3$, $Q = 0.2$ and $Q = 0.17$ (black curves). The light-blue curve shows the total number of events as a function of the maximum detectable recoil energy using $Q = 1$.

90 days of running => s/n = 0.92*90/sqrt(8.5*90) = 3

3 sigma detection in 90 days!

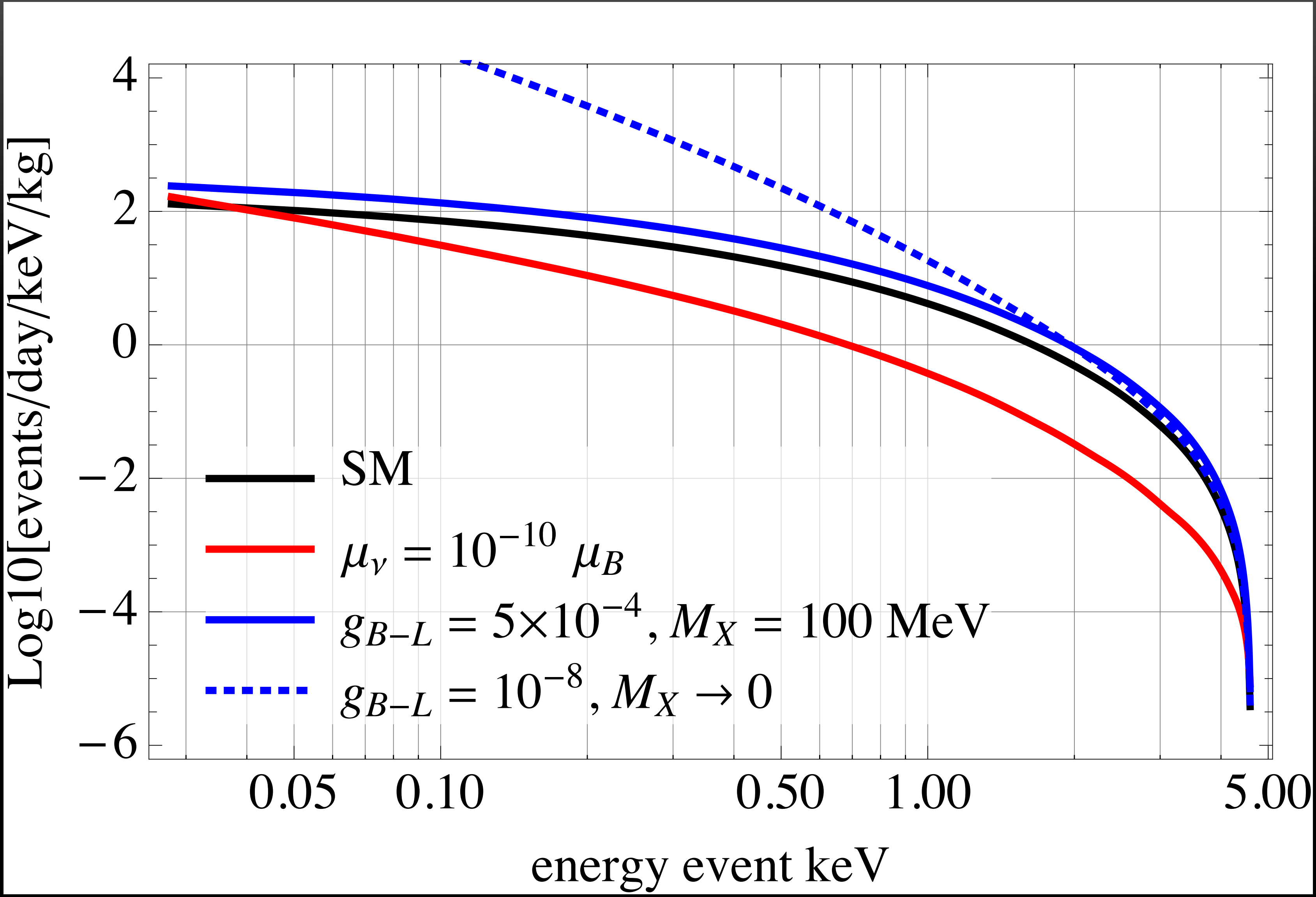
Moroni et al 2014 arXiv:1405.5761
Accepted in PRD 2015

TIMELINE

- We started discussion of taking early generation DAMIC detectors to ANGRA in 2012, but did not have a good way to fund this. Was considered outside the scope of a detector R&D project in a review in 2012.
- LDRD gave us the opportunity install a prototype for this in 2014.
  - Detector Shipping August-September 2014
  - Detector installation and first data October-November 2014 (10 grams)
  - Initial operations supported by experts from FNAL(LDRD) and UNAM(Mexico)
  - Continuous operation now supported by local team (UFRJ + CBPF)
  - Full shield assembly completed July 2015
  - August 2015 – full month of full power data
  - September 2015 – full month of shutdown
- LDRD also allowed us to build a real collaboration around this idea including institutions in Paraguay, Brazil, Switzerland, Mexico and Argentina
- Next: with a good background measurement we will know how much mass is needed for a significant detection. Complete the detector array to do this detection. A proposal to our partners for ~$200K . 100g of active mass.

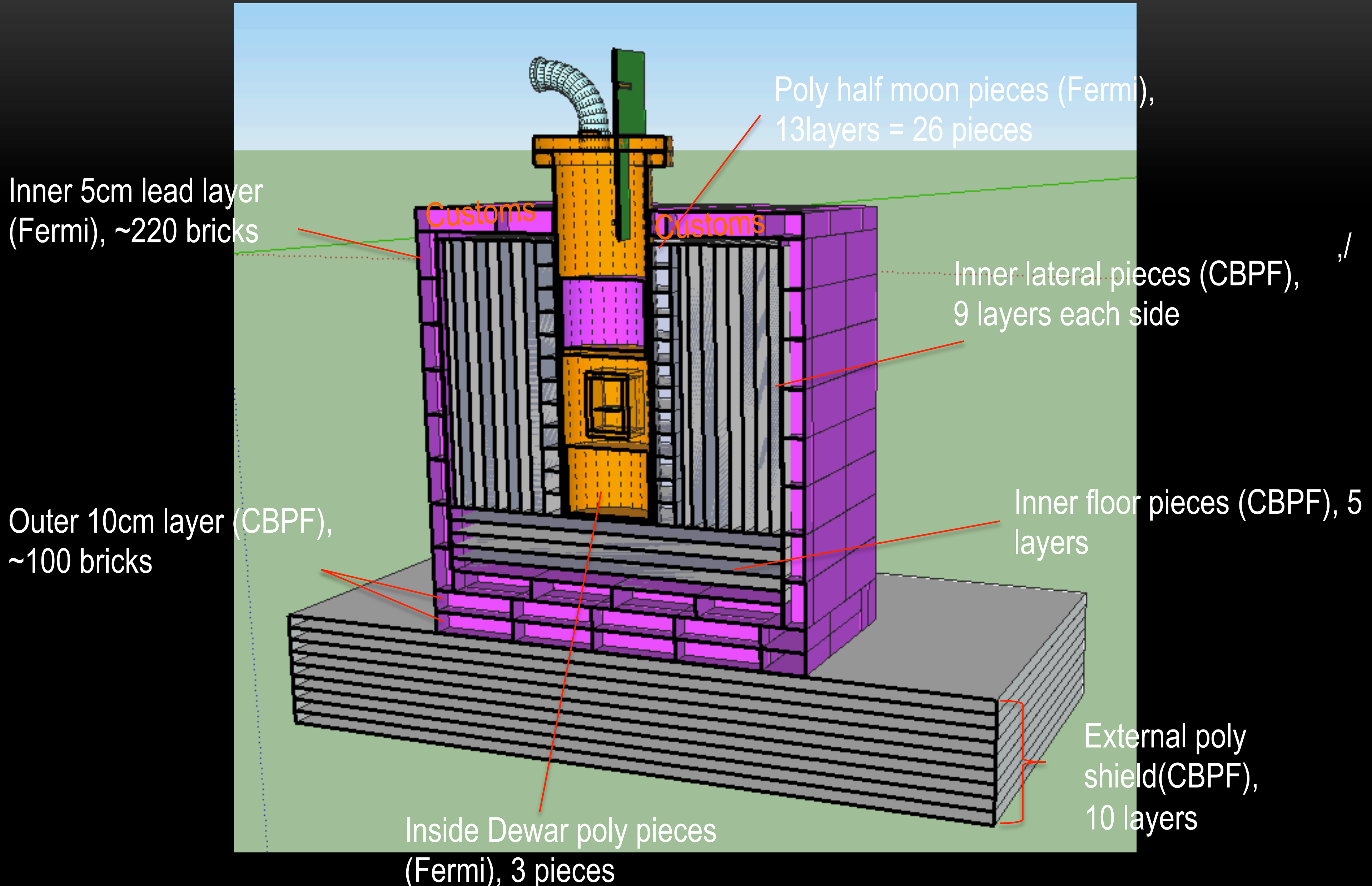
WHY IS THIS INTERESTING?

- Nobody has been able to see neutrino coherent scattering.
- Window for new physics:
  - Non Standard interactions
  - Neutrino Anomalous Magnetic Moment
  - Very important for future Dark Matter searches
  - New tool for neutrino experiments (very short baseline oscillation experiments – low energy)
- Technological applications:
  - Neutrinos could be used to monitor reactors

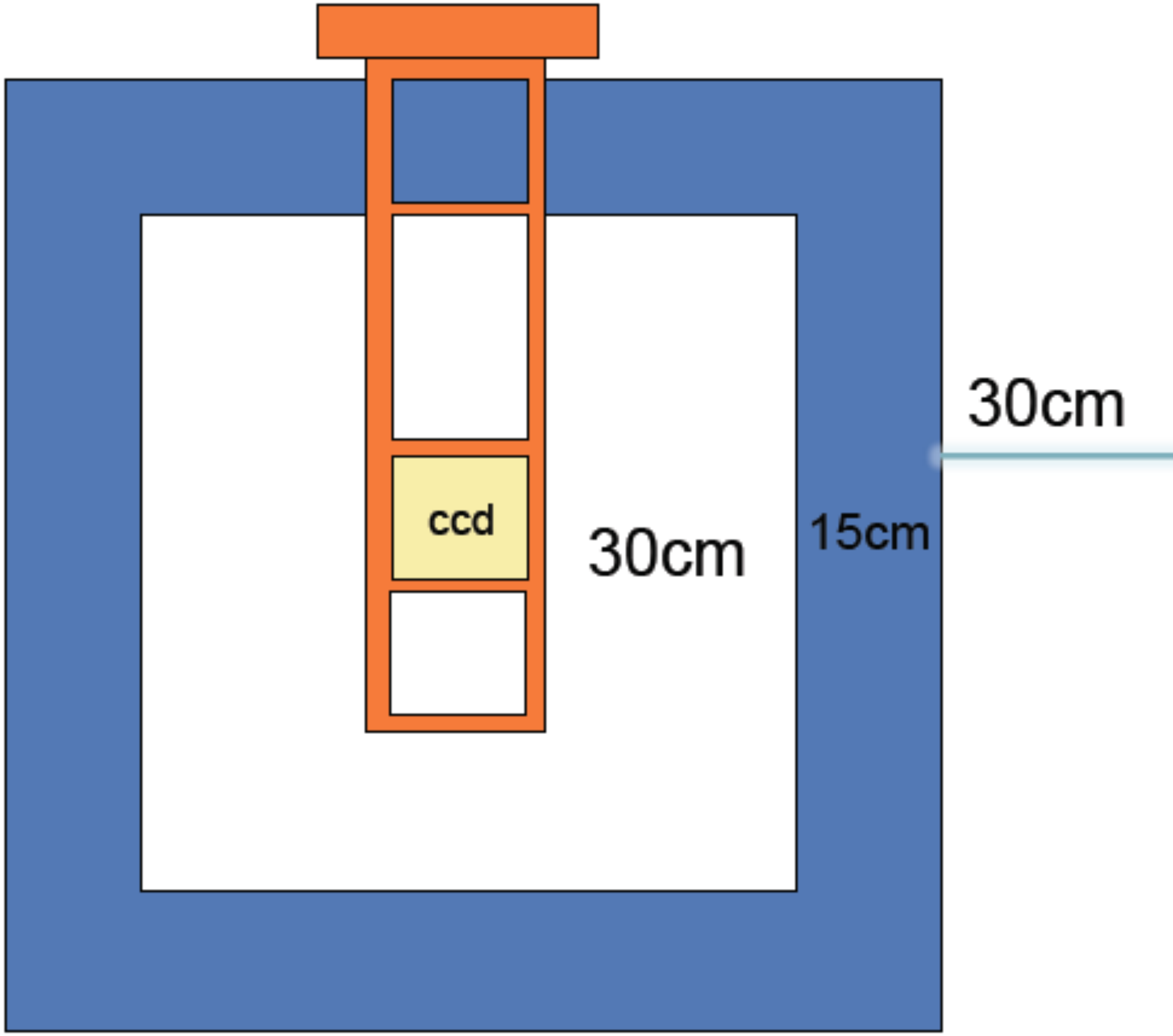


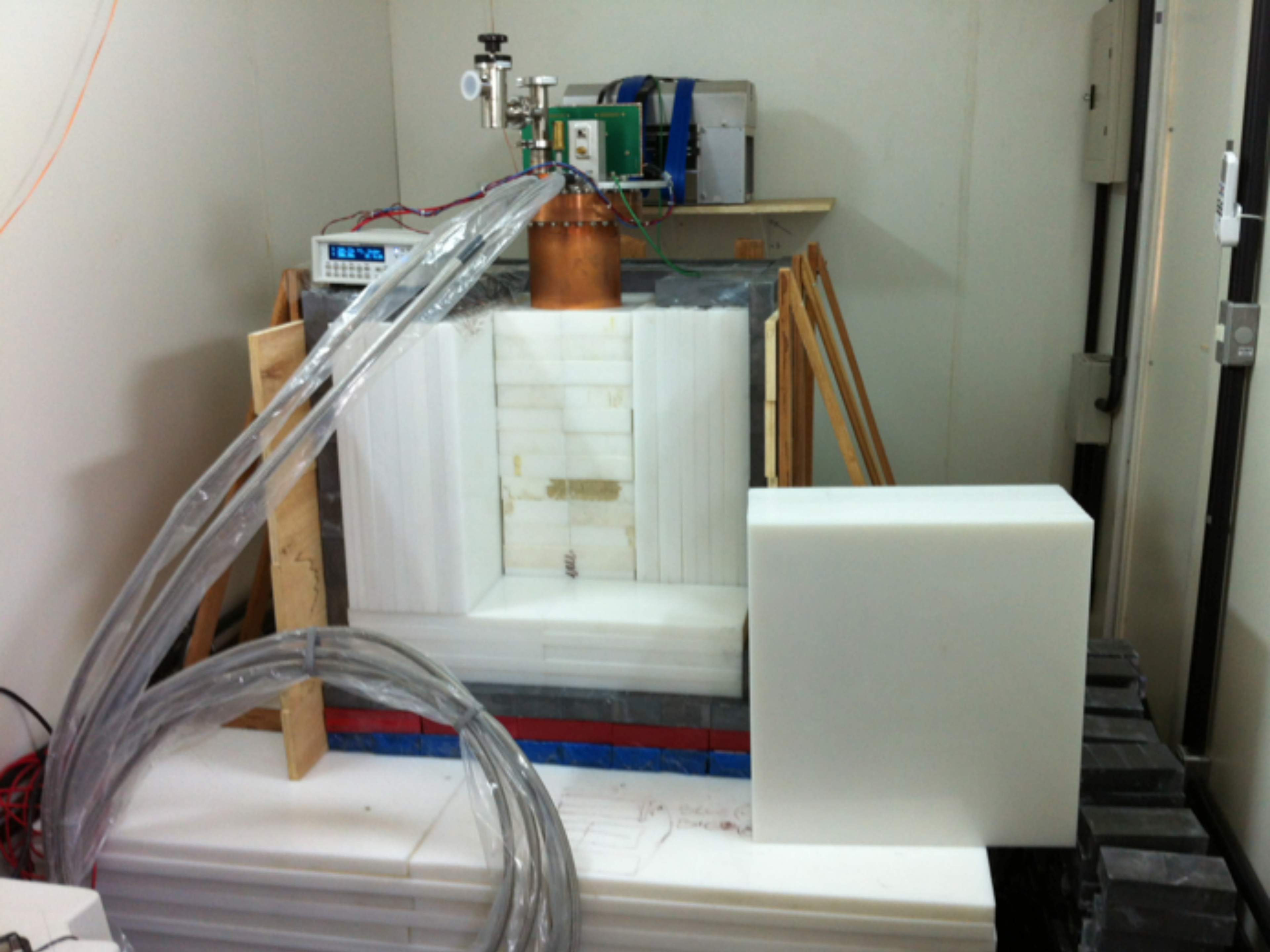
Early science. Even with a small detector (10g) it could be possible to do some early science by looking at exotic models where the rate of expected recoils at low energies could be x100 more than the SM. (Thanks Roni Harnik et al.)

Current shield.

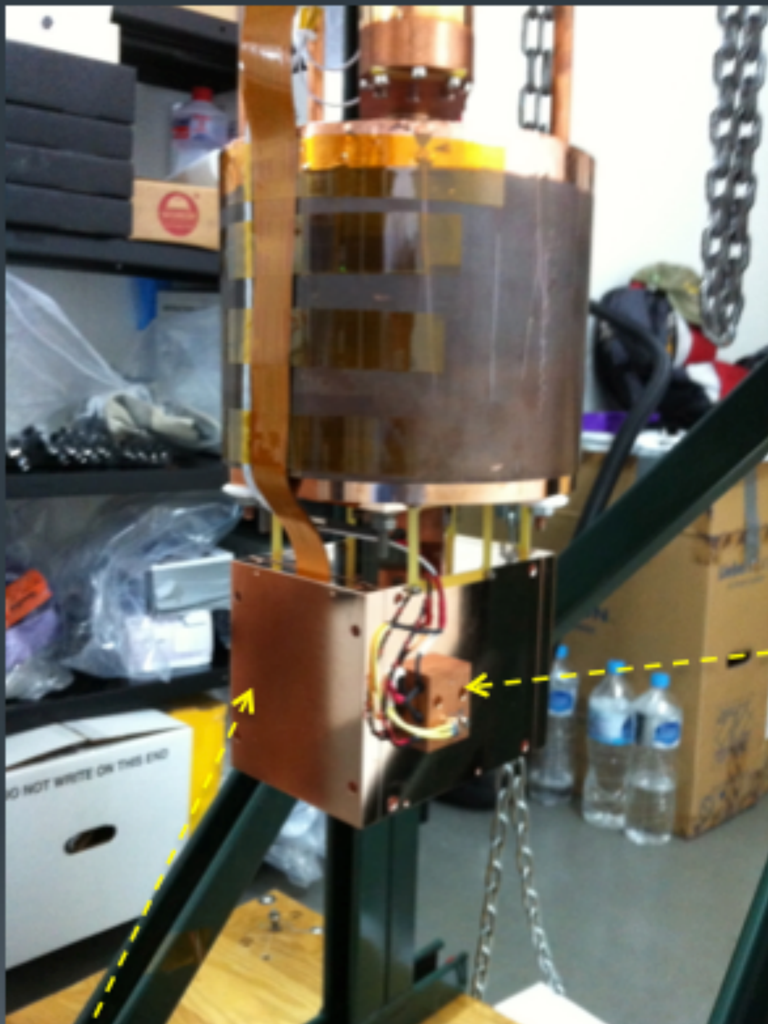


FINAL shield (July 2015)



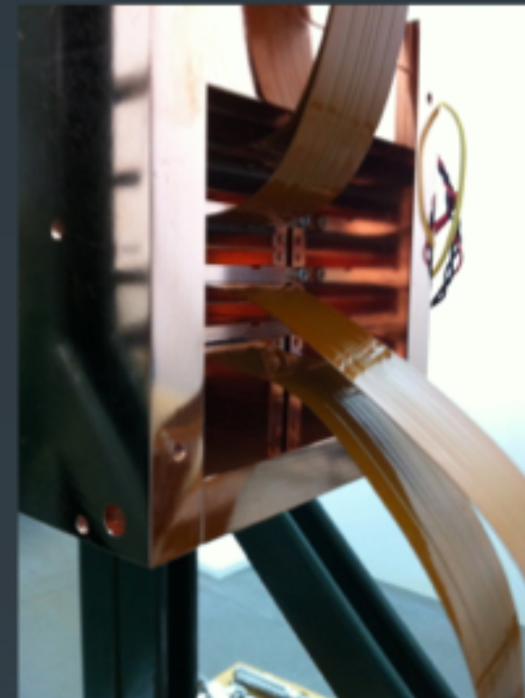


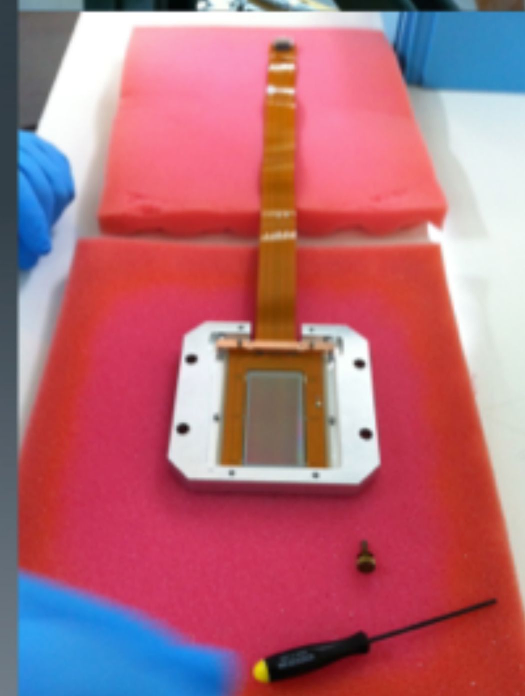
Detector configuration (November 9th, 2014)



Heater
Temp. sensor

Front door of the Cu-Box (CCD installatioin)





SOME OPERATION PARAMETERS

- 2 detectors reading out with 2e- of noise. The other two a somewhat higher, need to work a little on the data analysis to get their optimal performance. Not critical for this step of background measurement. Will limit early science.
- Running for 151 days (since 11/1/2014)
  - Main operation problems are power outage (we are not plugged to the stable power line of the reactor). Since November we had 7 power outages. For safety of the detectors we warmup when power is lost, it takes a few days to recover. Total of 35 lost days due to power outages.
  - In addition to this we had a vacuum pump failure: lost another 20 days. Now we have a replacement for a quick swap.
  - <u>We are running at 65% efficiency. Need to increase this!</u>
  - <u>Reactor running with better than 98% live time at full power.</u>
- A good start but work needed to improve operations.

THANKS

- LDRD program, and William Wester for making this happen. Fast and reasonable bureaucratic load. CONNIE would be stuck in the land of ideas without this program.
- Thanks FNAL Shipping team (Al Elste et al). Incredible amount of experience. Needed to send equipment to at low cost, safely and efficiently. I had to call them from inside the container asking for help with a Brazilian customs “weird” requirement. Responded within the hour, and solved the issue. Amazing!
- Thanks Irma Campos, Mala Seshadri and the travel department. Had to accommodate a few trips with, one with only a few days notice to fix a vacuum pump.
- Thanks Kevin Kuk. PPD super-technician. Now also certified to work at a nuclear power plant in Brazil. Had to negotiate his way to a long term visitor permit with the “Policia Federal”.
- Angra-II power plant staff.

LDRD: Summary

- All employees are invited to come up with new ideas and propose LDRD projects to test them out
- Soon, we hope to have about 20 active projects in all areas of accelerator, technical, computing, neutrino/energy/cosmic

- Next call for FY16 projects is expected end of April
- Already get started with the Preliminary Proposal and having discussions with your supervisor / Divisional management

- It will be exciting to see which new novel ideas lead to something that is lasting upon the Laboratory, or in science and technology.